To understand postoperative pulmonary complications so as to inform physiotherapy practice following adult cardiac surgery.

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To understand Postoperative Pulmonary Complications so as to inform Physiotherapy Practice following Adult Cardiac Surgery

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Submitted to Swansea University in fulfilment
of the requirements for the Degree of Master of Philosophy

2014

Summary (Abstract)

The development of postoperative pulmonary complications (PPC's) in patients undergoing cardiac surgery appears to require a more intensive service provision postoperatively and thus its impact on mortality and morbidity has been well recognised. Respiratory physiotherapy treatments aimed at improving or restoring pulmonary function following surgery has the unique opportunity to effect the prevalence of PPC's. However, the identification of potential determinants for the development of PPC's after cardiac surgery appears to be multi-factorial There is therefore a rationale to gain a deeper understanding and examine the patient profile to identify characteristics that potentially influence the development of this complication and furthermore its impact on clinical outcomes. This knowledge could inform physiotherapy practice within cardiothoracic surgery by optimizing the management of patients identified as high risk for this complication in the future.

Research Aim

To examine the nature and identifiable causal factors of Postoperative Pulmonary Complications following adult cardiac surgery in order to inform physiotherapy practice in patients identified as high risk.

Methods

This thesis utilized a number of research methodologies to address the research aim:

- A Systematic Review of the literature was undertaken to critically appraise evidence relating to risk factors for the development of postoperative pulmonary complications.
- Subsequently, a Narrative Review evaluated PPC's in the wider context in addressing the impact on morbidity and mortality, whilst exploring the potential role of physiotherapy initiatives to address this complication.
- A local Service Evaluation was conducted via a retrospective audit to evaluate 736 consecutive adult cardiac surgical patients to describe the local population and investigate patient characteristics and explore trends relating to patient and performance outcomes.

Conclusions

On average, 20% of the cardiac surgical population will develop postoperative pulmonary complications which requires a significantly prolonged stay in intensive care (5.04 days vs. 0.4 days; $p=0.001$). Left Ventricular function was the isolated preoperative characteristic that potentially influenced the development of postoperative pulmonary complications. The future recommendations for physiotherapy services including preoperative screening and early intervention strategies utilising left ventricular function as a physiological measure to identify patients at risk have been presented. These physiotherapy strategies for informing change have the potential to avert this complication and could have a considerable impact on the cardiothoracic service as a whole.

Declarations and Statements

I declare that the work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed .... (Candidate)
Date ....03.07.2015..................................

This thesis is the result of my own investigations, except where otherwise stated and other sources are acknowledged by footnotes giving explicit references and a bibliography is appended.

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I hereby give consent for the thesis, if accepted, to be available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organisations.

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Contents

Acknowledgements

Firstly, I would like to thank my research supervisors, Professor Ceri Phillips and Dr. Gareth Noble at Swansea University. Their assistance, guidance, understanding and immense knowledge provided throughout this entire process has been gratefully appreciated. I am also appreciative to the College of Human and Health Science at Swansea University for the student Bursary that I was awarded.

I would like to show my gratitude to my clinical supervisor Mr. Saeed Ashraf, for his enthusiasm towards the project and his insightful comments and feedback that have been thought-provoking and motivating. I extend my sincere thanks for the personal and professional support from my colleagues at the physiotherapy department, Morriston hospital.

Most importantly, this thesis would not have been accomplished without the support from my family. To my parents, Andrew and Kay, whose unwavering support, their words of encouragement and childcare that has helped me considerably throughout this process making its completion possible. To my husband Wayne and our beautiful daughter Ava, who I must extend my heartfelt thanks for your love and support and the sacrifice for the special times that I have missed out on due to the demands of this project. To our second child whose impending arrival into this world being only a few weeks away has been motivational influence for me and I cannot wait to meet you finally.

List of Abbreviations

ABG	Arterial Blood Gas Analysis
ABMU	Abertawe Bro Morgannwg University Health Board
AF	Atrial Fibrillation
AMED	Allied and Complementary Database
APACHE	Acute Physiology and Chronic Health Evaluation
ARDS	Acute Respiratory Distress Syndrome
BMI	Body Mass Index
BS	Breath Staking Technique
BSA	Body Surface Area
CABG	Coronary Artery Bypass Grafting
CAS	Coronary Artery Surgery
CASP	Critical Appraisal Skills Programme
CCF	Congestive Cardiac Failure
CCS	Canadian Cardiovascular Society
CHDU	Cardiac High Dependency Unit
CHF	Chronic Heart Failure
CINAHL	Cumulative Index to Nursing and Allied Health Database
CITU	Cardiac Intensive Therapy Unit
CmH20	Centimetre of Water
CONSORT	Consolidated Standards of Reporting Trials
COPD	Chronic Obstructive Pulmonary Disease
CPB	Cardio-Pulmonary Bypass
CPT	Chest Physiotherapy
CSP	Chartered Society of Physiotherapy
CT	Computed Tomography
CVA	Cerebrovascular Accident
CVC	Central Venous Catheter
CXR	Chest X-ray
DASI	Duke Activity Status Index

DBEX's	Deep Breathing Exercises
EDC	Effective Dynamic Compliance
EF	Ejection Fraction
EuroSCORE	European System for Cardiac Operative Risk Evaluation
etc.	*et cetera*- and other things
FET	Forced Expiratory Technique
FEV1	Forced Expiratory Volume in one second
FEV1/FVC	Ratio of FEV1 to FVC
FRC	Functional Residual Capacity
FVC	Forced Vital Capacity
G.P	General Practitioner
HQIP	Health Quality Improvement Partnership
HRQOL	Health Related Quality of Life
IABP	Intra-Aortic Balloon Pump
ICU	Intensive Care Unit
i.e.	*id est.*- that is
INR	International Normalized Ratio
IS	Incentive Spirometer
i.v.	Intravenous
KPa	Kilopascal
LOS	Length of Stay
LV	Left Ventricle
LVEF	Left Ventricular Ejection Fraction
LVF	Left Ventricular Failure
MI	Myocardial Infarction
ml/hr	milliliters per hour
mmHg	millimeter of mercury
N	no of subjects
NHS	National Health Service
NICOR	National Institute for Cardiovascular Outcomes Research
NSF	National Service Framework

NYHA	New York Heart Association functional classification
OSFI	Organ System Failure Index
PA	Pulmonary Artery
PCI	Percutaneous Coronary Intervention
PE	Pulmonary Embolism
PEDro	Physiotherapy Evidence Database
PFT	Pulmonary Function Tests
PMV	Prolonged Mechanical Ventilation
PPC	Postoperative Pulmonary Complication
ppm	procedures per million of the population
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta Analyses
Pts	Patients
QOL	Quality of Life
RBC	Red Blood Cells
RCT	Randomised Control Trial
REC	Research Ethics Committee
SAS	Specific Activity Scale
SCTS	Society for Cardiothoracic Surgery in Great Britain and Ireland
SD	Standard Deviation
SF-36	Short Form 36
SPSS	Software Package for the Social Sciences
STS	Society of Thoracic Surgeons
TLC	Total Lung Capacity
TTE	Trans-Thoracic Echocardiogram
UK	United Kingdom
μ.mol/l	micromoles/litre
VAP	Ventilator Associated Pneumonia
VC	Vital Capacity
Vs.	Versus
WAG	Welsh Assembly Government

>	Greater than
<	Less than
≥	Greater than or equal to
≤	Less than or equal to
%	Percent

List of Tables

List of Illustrations

1.0 Introduction

The cardiac unit at Abertawe Bro-Morgannwg University Health Board (ABMU) is a highly functioning unit that successfully undertakes in excess of 780 cardiac surgical procedures every year. Although, to a larger degree, the majority of patients who undergo cardiac surgery experience an uncomplicated postoperative recovery, a smaller proportion of patients do not. Postoperative Pulmonary Complications (PPC's) that occur following cardiac surgery anecdotally has been somewhat of a problem, as it requires a more intensive service provision throughout the recovery period. The development of PPC's appears to influence the duration of intensive care stay and the overall length of stay in hospital. Consequently, in view of the service as a whole, when a patient occupies an intensive care bed longer than anticipated, it can have a detrimental effect on the levels of surgical activity, as the capacity to undertake the number of procedures necessary is compromised.

Following cardiac surgery, respiratory physiotherapy treatments aim to improve or restore pulmonary function. With this in mind, the physiotherapy service has an opportunity to effect the level of PPC's that occur following surgery. However, prior to considering the potential impact of physiotherapy initiatives in reducing the incidence of PPC's, numerous pertinent questions are generated including: what is the incidence of PPC's? What is the impact of PPC's on clinical outcome? Which patients are at greater risk for the development of PPC's and can they be predicted? This information is fundamental to explore any future physiotherapy strategies to identify those at risk for PPC's and consider physiotherapy treatment initiatives to reduce this complication. This could potentially have a profound effect on the intensive care length of stay. Therefore, there is a service rationale for research to be directed to this area. However, currently this evidence is anecdotal as it is founded upon observational clinical experience and opinion.

Based upon these clinical observations and predictions, the Primary Research Aim is:

1.1 Research Aim:

To examine the nature and identifiable causal factors of postoperative pulmonary complications following adult cardiac surgery in order to inform physiotherapy practice in patients identified as high risk.

The research questions are:

1. What are the number of patients that develop PPC's following cardiac surgery?
2. Has the number of patients that develop PPC's increased over recent years?
3. Do patients who develop PPC's require a prolonged ITU stay?
4. Do patients that develop PPC's differ in their profile of pre-operative characteristics than those who do not?
5. Can patients who are at risk of developing PPC's based on their pre-operative characteristics be predicted?
6. What physiotherapy based interventions could be considered to manage patients who may be identified as high risk for the development of PPC's in the future?

1.2 Objectives

a) To undertake a Systematic Review of the literature surrounding the preoperative patient characteristics or risk factors for the development of PPC's.

b) To undertake a narrative review of physiotherapy practice in addressing PPC's following cardiac surgery.

c) To evaluate the literature centered upon postoperative complications in particular PPC's in the wider context in determining morbidity and mortality following cardiac surgery.

d) To review a quality framework that can be used to plan the design and implementation of a service evaluation.

e) To conduct a service evaluation of cardiac surgery at AMBU Cardiac Centre over a 2-year period to define the local cardiothoracic surgical population.

f) To generate a detailed patient based database from the service evaluation to examine the characteristics of patients that develop PPCs compared with patients that do not.

g) To examine the extent to which pre-operative patient characteristics can determine incidence of PPCs.

h) To determine the impact of the development of PPC's on Clinical Outcomes such as length of stay.

i) To consider the extent to which physiotherapy based preventive strategies can be put in place to reduce the incidence of PPC's.

1.3 Background

According to the British Heart Foundation, (2012), Heart and Circulatory diseases are the leading causes of death of men and women under 75 in the UK. Specifically, Coronary Ischaemic Heart Disease is thought to be the isolated cause of the 47,000 deaths that occurred in Wales during 2010. The NHS services currently in place to manage Circulatory diseases including Cardiac disease accounted for 8.8% of all NHS expenditure. This amounted to £459.8 million in 2009-2010. Consequently, the management of Cardiac Disease remains a key priority for NHS Wales in the future. (Welsh Assembly Government, 2012).

Coronary Artery Disease, resulting from atherosclerosis, and valve disorders, which can either be congenital or develop as one gets older, are the principal indications for adult cardiac surgery (Pryor and Prasad, 2002).The types of Cardiac Surgical Procedures vary, the most common being Coronary Artery Bypass Surgery, Valve repair or replacement, to the more complex surgical intervention that involves the Thoracic Aorta. The priority basis on which surgery is undertaken can range from Elective, In-House Urgent or an Emergency basis.

Coronary Artery Bypass Grafting Surgery (CABG) is usually undertaken in the management of Angina or when previous attempts of medical management or Interventional Cardiology (such as Coronary Angioplasty), have failed or are contraindicated. This procedure treats patients with either a narrowing or a blockage in their coronary arteries. Its aim is to restore blood flow and oxygen to the myocardium. During this procedure, an artery, most commonly the Internal Mammary Artery and/or Vein i.e. Saphenous Vein, is harvested from the body and is used as a 'graft' or 'conduit'. These vessels are used to reroute the blood around the blocked or narrowed artery. A patient may require several bypass grafts depending on the extent of the disease. (Pryor and Prasad, 2002)

Also noted by Pryor and Prasad (2002), the treatment of Heart Valve Disorders or Dysfunction are necessary as a result of childhood rheumatic fever, congenital abnormalities, endocarditis or heart failure. These conditions can compromise the competency of the valves and lead to either a Stenosis (narrowing) or a Regurgitation (leaking). The most common valves to require surgery are the Aortic and Mitral Valves. Replacement valves are usually mechanical prostheses or bio-prostheses (i.e. tissue valves). Some surgeons prefer to undertake a surgical repair of the valve rather than a replacement.

Frequently, patients can require both CABG and Valve replacement surgery together. In undertaking CABG surgery with concomitant procedures, although the surgery is longer in duration, it is also argued that the operative risk is greater (Bridgewater et al, 2008). Furthermore, more complex cardiac surgical procedures, for example, surgery to the great vessels such as the Thoracic Aorta are required when a dilation of the wall of the vessel occurs and an aneurysm is confirmed. This is also a considerably longer and more complex surgery and is thought to be a high risk procedure (Bridgewater et al, 2008).

1.4 Prevalence and Surgical Demand

According to the World Heart Federation (2014), the total number of deaths due to ischaemic heart disease in the world read 7.2 million, according to the world health organisation causes of death 2008 summary tables. The number of deaths from ischaemic heart disease in each region across the globe are illustrated in Figure 1, as shown below.

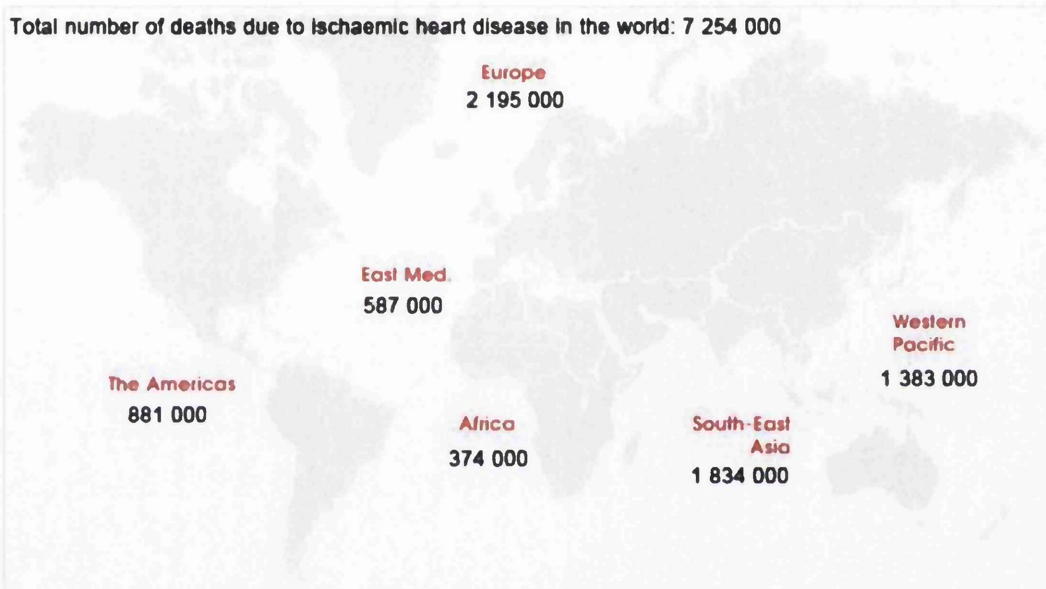

Figure 1: The global incidence of death due to ischaemic heart disease World Heart Federation (2014)

Within the U.K., the number of cardiac surgical procedures in Wales performed in 2010 was 1,382, accounting for 455.6 procedures per million (ppm) of the population. In England, the rates are higher, with 30, 231 procedures undertaken for 578.0 pp, for the same financial year (NICOR, 2011). Since, 2002, there have consistently been over 30, 000 cardiac surgical procedures carried out in England and Wales every year (NICOR, 2011).

At ABMU, where this research was undertaken, approximately 780 open heart operations are performed each year and the Cardiac Centre provides Tertiary Cardiac Services for a population of 933,000 in Swansea and West Wales (Abertawe Bro-Morgannwg University Health Board, 2012).

Over recent years, the demand for open heart surgery has increased which has been concurrently proposed to be attributed to the advances in medical treatment i.e. drugs and Interventional Cardiology Procedures such as Balloon Angioplasty and Stents (Ferguson et al, 2002; Weissman, 2004). This has provided treatment for patients with single or two-vessel disease (Ferguson et al, 2002). Subsequently, a larger proportion of patients now present for Cardiac Surgery in the UK with more advanced three-vessel disease. Consequently increasing the predicted operative risk by 30% (Ferguson et al, 2002).

1.5. Current Practice

1.5.1 Pre-operative Assessment

When a patient is referred to the Cardiac Centre by either GP or the referring Physician for consideration of Cardiac Surgery, a pre-operative assessment is undertaken. The principal aim is to confirm the diagnosis of a cardiac pathology. Patients can present with symptoms including angina, dyspnoea, orthopnoea, limited exercise tolerance and syncope (Cornelissen and Arrowsmith, 2006). The severity of the symptoms are assessed according to the Canadian Cardiovascular Society (CCS) for the classification of angina, as shown below:

Table 1: Canadian Cardiovascular Society Grading of Angina Pectoris Grade Description

Grade	Description
I	Ordinary physical activity does not cause angina, such as walking and climbing stairs. Angina with strenuous or rapid or prolonged exertion at work or recreation
II	Slight limitation of ordinary activity. Walking or climbing stairs rapidly, walking uphill, walking or stair climbing after meals, or in cold, or in wind, or under emotional stress, or only during the few hours after awakening. Walking more than two blocks on the level and climbing more than one flight of ordinary stairs at a normal pace and in normal conditions
III	Marked limitation of ordinary physical activity. Walking one or two blocks on the level and climbing one flight of stairs in normal conditions and at normal pace
IV	Inability to carry on any physical activity without discomfort, anginal syndrome may be present at rest

(Campeau, 1976)

Further to this, as part of the preoperative evaluation, according to the New York Heart Association functional classification (NYHA), symptoms can be further classified into 4 stages as shown below:

Table 2: NYHA Description of Functional Classification

Class	Functional Capacity
I	Cardiac disease, but no symptoms and no limitation in ordinary physical activity, e.g. shortness of breath when walking, climbing stairs etc.
II	Mild symptoms (mild shortness of breath and/or angina) and slight limitation during ordinary activity.
III	Marked limitation in activity due to symptoms, even during less-than-ordinary activity, e.g. walking short distances (20–100 m). Comfortable only at rest.
IV	Severe limitations. Experiences symptoms even while at rest. Mostly bedbound patients.

(The Criteria Committee of the New York Heart Association, 1994; Moorjani, Voila and Ohri, 2011)

Furthermore, patients prior to surgical interventions are screened according to potential risk factors. These include Age, Gender, Hypertension, Hyperlipidemia, Diabetes, Smoking history, Obesity, Previous Operations and Family history. The consultant then explores a patient's medical history further to determine any other systems of dysfunction. This may include Pulmonary, Gastro-Intestinal or Peripheral Vascular Disease, Renal status or a history of cerebral events.

Following a detailed history, it is usual practice for Cardiac Catheterisation and Coronary Angiography diagnostic assessment to be performed. Most commonly, this is a day-case diagnostic procedure that has the ability to visualise the lumen of the coronary arteries to reveal the extent of the disease.

Furthermore, a Transthoracic Echocardiogram (TTE), which is an ultrasound scan of the heart and its internal structures is also requested. This imaging procedure allows the consultant to comprehensively evaluate the function of the right and left ventricles at different points of the cardiac cycle, analysing the competency of the valves, the walls of the heart and the pericardium.

Additionally, in clinical practise, Smetana (2003) reports that pre-operative pulmonary function testing (PFT's) can be requested, although this appears to be on an ad-hoc basis. PFT's are undertaken in patients with unexplained dyspnoea or those with exercise intolerance and those with Chronic Obstructive Pulmonary Disease (COPD) or asthma, when uncertainty exists regarding the status of airflow obstruction in comparison to baseline values (Kroenke, 1993). Smetana (2003) advocates that clinicians should not routinely recommend pre-operative spirometry before high risk surgery, as it is no more accurate in predicting risk than clinical evaluation. However, Adabag et al (2010) promotes the use of PFT prior to cardiac surgery with the aid of reclassifying the COPD status as they postulate that the data generated provides vital prognostic information that risk stratification models do not capture.

Following completion of this pre-operative assessment, together with the findings of the angiogram and TTE, plus any other investigations requested, the cardiac procedure is proposed as the clinical option to manage the particular patient's case.

1.5.2 Standard Operative Practice

At ABMU, all open heart surgery is performed through a median sternotomy incision allowing exposure of the heart and vessels (Adair and Kon, 1994; Weissman, 2004) and uses Cardiopulmonary Bypass (CPB) as standard operative practice. CPB permits surgery to be performed on the heart by excluding the heart and lungs from the circulation (Moorjani, Voila and Ohri, 2011). CPB involves inserting a cannula into the right atrium which drains the blood from the heart into the CPB machine. The machine then filters and oxygenates the blood and returns the blood back to the systemic circulation via an additional cannula, placed into the ascending aorta (Pryor & Prasad, 2002). The purpose of the CPB machine is to maintain adequate gaseous exchange and systemic organ perfusion but also to control optimal body temperature (Moorjani, Voila and Ohri, 2011).

Once bypass is established for a period of two minutes and the patient's haemodynamic status is stable, lung ventilatory arrest occurs and the heart is arrested with cold blood cardioplegia, as the aorta is cross clamped. (Crawford, DiMarco & Paulus 2010; Moorjani, Voila and Ohri, 2011). The administration of a cold cardioplegic solution and topical cooling results in a hypothermic arrest (Pryor & Prasad, 2002). This step in the procedure, when reducing body temperature to a mild hypothermia, at approximately 32°C, is crucial. During the operation when the aorta is cross clamped, the coronary arteries are deprived of oxygenated blood resulting in ischaemia of the myocardium. Therefore, the principle of hypothermia is crucial in myocardial protection and protection of neural tissue, as hypothermia is found to reduce oxygen consumption and metabolic rate (Moorjani, Voila and Ohri, 2011). Following this period, the surgeon is able to operate on a non-beating heart. On completion, systemic re-warming occurs, allowing the heart to gradually refill and the chest cavity is closed which concludes the surgical procedure.

1.5.3 Post-Operative Management

Within ABMU the Cardiac Surgery Division is divided into three key areas. Following surgery, the patient is transferred to Cardiac ITU, then the patient will progress to the Cardiac High Dependency Unit (CHDU) and finally to the ward, prior to discharge home. At this institution, the anticipated length of stay for patients undergoing a CABG procedure is approximately 5 to 7 days, and for those following valve replacement surgery, the expected length of stay is slightly longer from 7 to 10 days. It is important to acknowledge that the anticipated length of stay is based upon those patients who follow a routine, uncomplicated pathway of care. According to Wynne (2003), the average length of stay following a cardiac surgical procedure in the UK is 8 days.

1.5.4 Mechanical Ventilation

On Cardiac Intensive Therapy Unit (CITU), a period of Mechanical Ventilation is necessary following a cardiac surgical procedure using hypothermic CPB. Whilst Normo-thermia is established, the initial period of sedation and analgesia is mandatory. This is thought to reduce the stress induced sympathetic activation thus minimising hypertension and myocardial oxygen demand during the initial critical stage (Arom et al, 1995; Habib et al, 1996). The general consensus following Cardiac Surgery is that patients are extubated within 6-8 hours postoperatively (Yende and Wunderink, 2002), reflecting a change in culture promoting early tracheal extubation.

1.5.5 Early Extubation

At ABMU Cardiac Centre, early extubation is a practice that has become more prevalent, focusing on expediting from mechanical ventilation in less than 8 hours. This method has been vastly researched and concurrently promoted to be a safe practice without increase incidence of morbidity and mortality (London et al, 1996; Cheng et al, 1996; Johnson et al, 1997; Hawkes et al, 2004). An initiative such as early extubation practice following cardiac surgery aims to accelerate the patient's discharge from the intensive care unit.

Further to this, another concept that aims to facilitate ITU discharge and reduce the demand on critical resources is "Rapid Recovery Management" which has been discussed since the early nineties (Dunstan & Riddle, 1997; Naughton et al, 2005). The key component of this initiative strives not only towards early extubation but an accelerated discharge from ITU thus allowing hospital discharge in 3 to 5 days following cardiac surgery, without a compromise in patient care (Dunstan & Riddle, 1997). Currently, at ABMU cardiac centre, the "rapid recovery" pathway is not in place, although there is a strive towards achieving the same desired outcomes and where possible, some patients are so called "fast-tracked" out of ITU to the high dependency unit. However, this applies to only those candidates deemed suitable for early discharge, which raises the question, if the patient profile within cardiac surgery has changed, is the ability to facilitate "rapid recovery" under threat in the future?

However, as healthcare professionals, within the current climate of the continual drive for cost-effective healthcare, clinical practice should aspire to meet and facilitate these desired outcomes. These initiatives are widely recognised to yield beneficial cost savings by reducing the length of intensive care stay and with the increase demand for cardiac surgery, thus the opportunity to undertake more cardiac operations. (Johnson et al, 1997; Hawkes et al, 2004; Rajakaruna et al, 2005; Zhu et al, 2012)

Nevertheless, despite early extubation practice, a number of patients still require a period of prolonged mechanical ventilation (PMV) (Canver and Chanda, 2003; Pappalardo et al, 2004). This is associated with an increased risk of morbidity and mortality and specifically nosocomial infections (Fagon, 1996). It is of the opinion that a failure of a patient to be extubated is a sicker patient.

1.6 Patient Profile

As previously discussed, the developments in Percutaneous Cardiology Intervention (PCI), for example stents and angioplasty procedures, in addition to medical therapy that provide effective management for those patients with single or two-vessel disease has consequently altered the profile/characteristics of the patient that is now often referred for cardiac surgery (Ferguson et al, 2002). The cardiac surgical candidate now presents for surgery with a more advanced disease state, frequently involving three vessels or more. Further to this patients are now perceived to be older, frailer, exhibiting several other co-morbidities and perhaps some patients are now requiring their surgery for the second time (Ferguson et al, 2002; Canver and Chanda, 2003; Hulzebos et al, 2006). It would appear as though there is an average trend towards 'sicker' patients or those with more health-related risks are requiring cardiac surgery today (Engoren et al, 1999).

1.6.1 Risk Factors

It is commonly reported that patients with atherosclerotic disease or valve dysfunction requiring cardiac surgery are also likely to present with chronic co-morbidities, therefore as part of the extensive preoperative evaluation, an investigation into the presence of risk factors will be sought after (Cornelissen and Arrowsmith, 2006). There is a wealth of literature into risk factors for complications following cardiac surgery. These include gender, advancing age, with a mean age of 65.1 years (Ferguson et al, 2002) and over recent times, octogenarian patients have increasingly presented for surgical intervention.

In accordance with risk stratification measures, chronic lung disease appears as a pertinent and clinically relevant risk factor (Saleh et al, 2012). Patients undergoing cardiac surgery with a history of pulmonary impairment, in particular, with COPD have found to be at greater risk of pulmonary morbidity (Cohen et al, 1995) and adverse surgical outcome including early mortality (Saleh et al, 2012).

Furthermore, patients who have a history of cigarette smoking, either current or ex-smokers, are thought to pose a greater risk of pulmonary morbidity. Factors responsible for developing complications, particularly pulmonary complications following surgery are thought to be mucus hyper-secretion, an impairment in tracheobronchial clearance and small airway narrowing secondary to cigarette smoking (Ashraf et al, 2004).

A defining characteristic of patients that require cardiac surgery is heart failure. Although coronary artery disease is the most common precipitating factor in 60 to 70% of cases, it is important to address its complex nature in terms of its pathophysiology, in order to understand its clinical relevance as a pertinent risk factor (Klein, Vuylsteke and Nashef, 2008). It's Definition according to Moorjani, Viola and Ohri (2011, p.383) is:

> *"Heart failure is a complex clinical syndrome resulting from any structural or functional cardiac disorder that impairs the ability of the ventricle to fill or eject blood, and results in a cardiac output that is inadequate to meet the metabolic demands of the body".*

Currently with efficient pre-operative screening, it is often highlighted that many patients have varying degrees of impaired cardiac function and thus a reduced cardiac output. Left sided heart failure involves the Left Ventricle (LV) of the heart, which receives oxygenated blood from the pulmonary system via the left atria and pumps blood throughout the body. In the management of cardiac disease, the function of the LV is paramount, as any compromise in its ability to pump blood and perfuse the entire body is significant. By defining the level function of the LV into 'Good, Moderate and Poor' is an important step in the treatment of heart failure and acute cardiac disease. When the LV starts to loose its ability to pump blood efficiently, this is termed LV systolic heart failure as it refers to the weakening of the LV wall. This damage to the myocardium can occur as a consequence of an MI which results in an abnormality in wall motion. In order to quantify this, the Ejection Fraction (EF) represents a percentage measurement of how much blood is pumped out of the LV with each contraction. From a clinical perspective, an EF of greater than 50% is classed as 'Good', an EF of 30% to 50% is 'Moderate' and less than 30% is 'Poor' LV function (Society for Cardiothoracic Surgery (SCTS), 2013). The clinical manifestations of left sided heart failure can range from dyspnoea, orthopnea and paroxysmal nocturnal dyspnoea, weight loss, muscle wasting to reduced exercise tolerance (Moorjani, Voila and Ohri, 2011).

In comparison, the right ventricle receives used blood that is returned to the heart via the superior and inferior vena cava, though the right atrium and is blood is then moved to the right ventricle and pumped back into the pulmonary system to be replenished with oxygen. Right sided failure usually occurs as a result of left sided heart failure. When the function of the left ventricle is impaired, there is an increase in fluid pressure that is in effect transferred back through the lungs, and consequently damaging the right side of the heart (American Heart Association, 2012). Subsequently, when the right ventricle looses power, blood backs up in the veins, exhibited by symptoms of peripheral oedema, ascites and hepatic congestion (Moorjani, Viola and Ohri, 2011). The diagram below displays the clinical manifestations of heart failure (Figure 2).

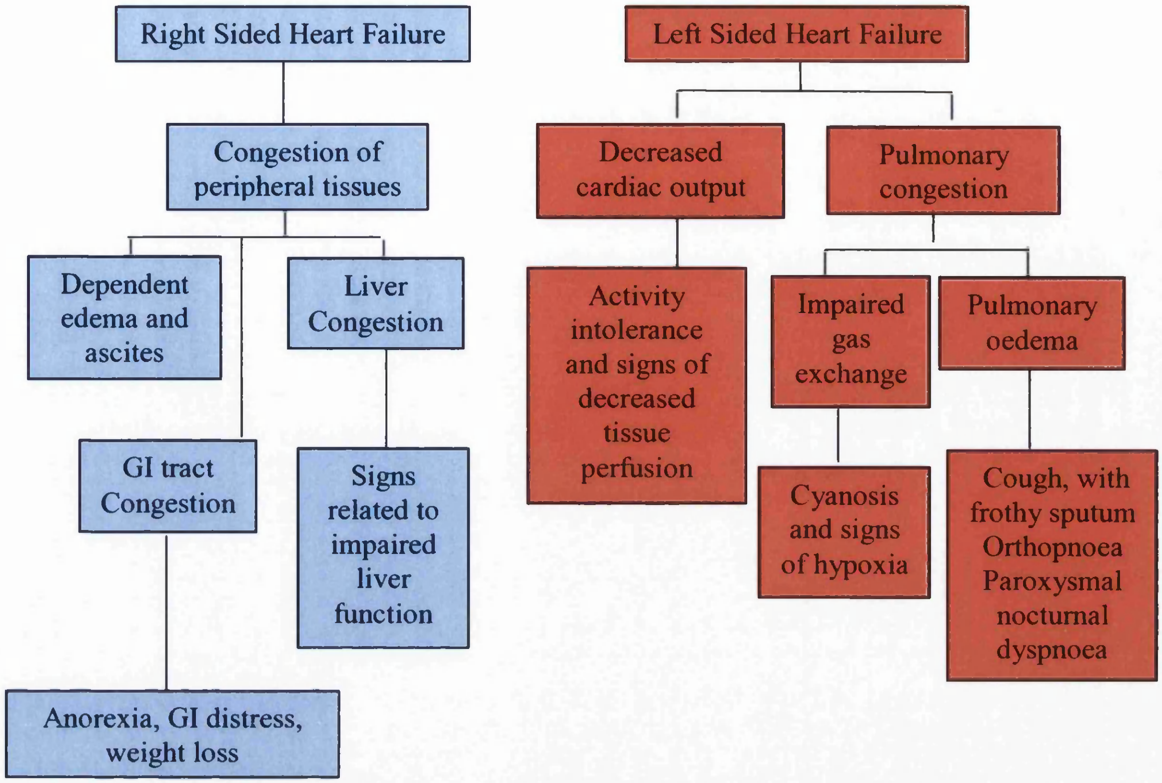

Figure 2: Clinical Manifestations of Heart Failure (Quizlet, 2013)

Ultimately, the progression of heart failure and its impact on cardiac output impairs perfusion to systemic organs, which is termed Congestive Heart Failure (CHF). This elicits a powerful protective reaction in an attempt to maintain the blood pressure and blood flow. These mechanisms include the activation of the sympathetic nervous system causing vasoconstriction, increasing the peripheral vascular resistance to increase the blood pressure, however, in effect makes the weak LV work harder. Additionally, the release of endogenous noradrenaline and antidiuretic hormone, i.e. vasopressin, is also triggered. Further to this, there is an activation of renin-angiotensin aldosterone system which stimulates angiotensin to travel to the myocardium which promotes the remodeling of the myocardium causing the LV to thicken thus increasing ventricular mass. This is termed diastolic failure and is commonly caused by hypertension. Although with time, this remodelling of the ventricle reduces the volume of the chamber thus affecting the end-diastolic volume (Moorjani, Viola and Ohri, 2011). Although the mechanisms of compensation are initially beneficial, they eventually result in a vicious cycle of worsening heart failure (Kemp and Conte, 2012) further lowering cardiac output, thus producing hypo-perfusion of the tissues. Consequently, renal dysfunction occurs as a result of a reduction in urine output, resulting in fluid retention and the formation of oedema, i.e. pulmonary oedema leading to pulmonary impairment, and systemic oedema, affecting other organs such as the liver.

As previously highlighted, the NYHA classification of functional capacity can assess the severity of a patients symptoms but also can determine the extent of the degree of heart failure, ranging from Class I when a patient has no limitation to physical activity to Class IV whereby a patient is unable to carry out any physical activity (Cornelissen and Arrowsmith, 2006; Moorjani, Voila and Ohri, 2011). It is therefore important to consider how the varying degrees of heart failure reduces the necessary blood and oxygen to the systemic organs.

Consequently, this has an impact on patients who undergo Cardiac Surgery as patients often present as weak and fatigued, as a consequence to their impaired LV function. This predisposes them to the risk of postoperative complications (Weissman, 2004; Filsoufi et al, 2007) and heart failure is a disease that causes significant morbidity and is thought to carry a 50% risk of 5-year mortality (Kemp and Conte, 2012).

Other pre-operative risk factors thought to increase the risk of postoperative complications include age >70 years (Arom et al, 1995; Rady et al, 1997), Diabetes Mellitus, a history of cigarette smoking (Hulzebos et al, 2003) and NYHA Class IV (Engoren et al,1999) although the evidence is conflicting. Other studies have proposed numerous predictive independent variables linked to prolonged mechanical ventilation and pulmonary complications postoperatively. These are renal failure, congestive cardiac failure, angina, prolonged CPB time >90 minutes (Rady et al, 1997; Canver and Chanda, 2003), emergency and re-do surgery (Rady et al, 1997; Pappalardo et al, 2004), re-operation for bleeding (Arom et al, 1995; Canver and Chanda, 2003) have been consistently proposed. The numerous risk factors identified are those that have been consistently documented by others (Christakis et al, 1996; Habib et al 1996; Bando et al, 1997; Johnson et al, 2007). Additionally, the presence of obesity in patients undergoing cardiac surgery has been shown to affect respiratory mechanics and elongate the narrowing of the airway and resistance in the initial critical postoperative days. Obesity together with the inclusion of CPB is suggested to prolong the deterioration in the respiratory system (Albu et al, 2010).

The evolving patient profile to this point has been introduced in terms of pre-surgical health status as risk factors and their potential influence as predictors of outcome. However, for some patients, psychosocial variables are formidable, as it is thought that cardiac surgery can induce both emotional and psychological responses in patients. According to Rymaszewska et al (2003), 55% of patients were found to have high levels of preoperative anxiety. The authors propose that depression and anxiety can persist following surgery, worsening a patients psychosocial functioning and quality of life (Rymaszewska et al, 2003). Furthermore, depression and anxiety preoperatively has also been associated with an increased mortality risk following CABG surgery (Tully et al, 2008) and other short term consequences include adjustment disorder, major depression and clinically relevant cognitive deficits. Although, cardiac surgery has been associated with an improvement in HRQOL (Rothenhäusier et al, 2005).

With the vast research undertaken into the risk factors for complications following Adult Cardiac Surgery, there is an apparent need to review its impact on clinical outcomes and also question if the research insinuates that certain sub-sections of patients may be at higher risk for postoperative complications, should our clinical practice and treatment strategies alter?

The evaluation and appraisal of the risk factors for complications following surgery can be found in the systematic review, Chapter 2.0

1.7 Risk Stratification

Within the extensive preoperative investigations, an essential component of patient assessment when a surgeon considers a proposed procedure, is the evaluation of risk. Predicted operative mortality is often the main outcome of the scoring systems. It is estimated that the operative mortality for patients undergoing an elective coronary artery bypass procedure in the UK is 1.5% (Bridgewater, 2009). This figure of operative mortality risk is calculated using risk stratification models, of which there are many and they vary in terms of their complexity. It appears as though some prediction models are simple and user friendly i.e. Parsonnet or EuroSCORE, based on patient derived data (Parsonnet, 1989; Nashef et al, 1999) and some are more complex statistical algorithms such as the Logistical EuroSCORE (Roques et al, 2003).

Historically, at ABMU Cardiac Centre, the Parsonnet method of uniform stratification of risk was employed as it was the first, simple, validated, preoperative scoring system proposed for adult cardiac surgery. First introduced in 1989 the "Initial Parsonnet's Score" identified 14 independent risk factors for mortality within 30-days following cardiac surgery, and was based upon patient and surgery related factors, as shown below:

Table 3: Initial Parsonnet Score

Risk factors	**Assigned Weight**
Female gender	1
Morbid obesity (≥1,5 x ideal weight)	3
Diabetes	3
Hypertension (systolic blood pressure\140 mm Hg)	3
Ejection fraction *> 50%* *30-49%* *<30%*	 0 2 4
Age *70-74* *75-79* *>80*	 7 12 20
Re-operation *First*	 5

Second	10
Preoperative Intra-Aortic Balloon Pump	20
Left Ventricular Aneurysm	5
Emergency surgery following PTCA or catherisation complications	10
Dialysis Dependency (peritoneal dialysis or haemodialysis)	10
Catastrophic states (acute structural defect, cardiogenic shock, acute renal failure)	10-50
Other rare circumstances (paraplegia, pacemaker dependency, severe asthma, congenital heart disease in adult)	2-10
Mitral surgery	5
Mitral surgery and pulmonary artery pressure >60 mmHg	8
Aortic surgery	5
Aortic surgery and pressure gradient >120mmHg	7
CABG at the time of valve surgery	2

(Parsonnet et al, 1989; Keogh and Kinsman, 2004)

However, over time it was argued that 2 of the risk factors allowed subjective scoring which reduced the reliability of the system as there was a tendency to over predict the operative risk (Keogh and Kinsman, 2004; Rees and Dineschandra (2006).

Subsequently, the original score was later modified to include 30 new risk factors which is now referred to as the "Modified Parsonnet's Score".

Table 4: Modified Parsonnet Score

Risk factors	**Assigned Weight**
Female gender	1
Morbid obesity (≥1,5 x ideal weight)	3
Diabetes	3
Hypertension (systolic blood pressure\140 mm Hg)	3
Ejection fraction *> 50%* *30-49%* *<30%*	 0 2 4
Age *70-74* *75-79* *>80*	 7 12 20
Re-operation *First* *Second*	 5 10
Preoperative Intra-Aortic Balloon Pump	20
Left Ventricular Aneurysm	5

Emergency surgery following Percutaneous Transluminal Coronary Angioplasty or catherisation complications	10
Dialysis Dependency (peritoneal dialysis or haemodialysis)	10
Catastrophic states (acute structural defect, cardiogenic shock, acute renal failure)	10-50
Other rare circumstances (paraplegia, pacemaker dependency, severe asthma, congenital heart disease in adult)	2-10
Mitral surgery	5
Mitral surgery and pulmonary artery pressure >60 mmHg	8
Aortic surgery	5
Aortic surgery and pressure gradient >120mmHg	7
CABG at the time of valve surgery	2
Left coronary main stenosis >90%	3
Unstable angina	3
Ventricular tachycardia or fibrillation	5
Cardiogenic shock	25
Myocardial infarction during the last 48h	7
Cardiac insufficiency	5
Permanent pacemaker in place	2
Active endocarditis	10
Post-myocardial infarction septal defect	20
Chronic pericarditis	5
Adult congenital heart disease	10
Chronic pulmonary obstructive disease	5
Mean pulmonary pressure $\geq$30 mmHg	10
Idiopathic thrombopenic purpura	10
Pre-operative intubation	5
Severe asthma	15
Lower limb arterial disease	2
Carotid arterial disease	7
Abdominal aortic aneurysm	5
Aortic dissection	10
Severe neurological disease	5
Severe hyperlipidaemia	3
Jehovah's witness	10
Preoperative therapy with antiplatelet agents	2
Severe chronic intoxication	3
Active AIDS	10
Active cancer	5
Long term corticosteroids or immunosuppressive therapy	2

(Kacila et al, 2010)

Based on the assigned weight of the risk factors, a calculated mortality risk score is yielded. A score of 0-4 was considered low risk with a predicted operative mortality of 1%; a score of 5-9 had an operative mortality of 5% (elevated risk); a score of 10-14, a mortality of 9% (significantly elevated risk); a score of 15-19 with a mortality of 17%

(high risk) and a score of greater than 19 was considered very high risk with a yielded mortality risk of 31% (Parsonnet et al (1989); Keogh and Kinsman, (2004).

Over time, it was argued that the impact of the variables had changed and that cardiac surgeons "out-performed" the Parsonnet score by a factor of 2 (Cornelissen & Arrowsmith, 2006). As a consequence, it was postulated that this had reduced the usefulness of the Parsonnet scoring system as risk and surgical performance measures (Keogh and Kinsman (2004); Cornelissen & Arrowsmith, 2006; Rees and Dineschandra, 2006).

Subsequently, at AMBU Cardiac Centre, there was a move to a newer, more robust risk assessment, The European System for Cardiac Operative Risk Evaluation or EuroSCORE was developed in the late 1990's (Nashef et al, 1999). Seventeen risk factors are weighted for the EuroSCORE system; nine are patient related, four are dependent on the preoperative cardiac status of the patient and four are dependent on the timing and the nature of the operation (Nashef et al, 1999).

Table 5: EuroSCORE: risk factors, definitions and weights

	Definition	Score
Patient Related Factors Age	Per 5 years or part thereof over 60 years	1
Sex	Female	1
Chronic Pulmonary Disease	Long term use of bronchodilators of steroids for lung disease	1
Extracardiac arteriopathy	Any one of the following: claudication, carotid occlusion or >50% stenosis, previous or planned intervention on the abdominal aorta, limb arteries or carotids	2
Neurological dysfunction	Disease severely affecting ambulation or day-to-day functioning	2
Previous cardiac surgery	Requiring opening of the pericardium	3
Serum creatinine	>200µ.mol/l preoperatively	2
Active endocarditis	Patients still under antibiotic treatment for endocarditis at the time of surgery	3
Critical preoperative state	Any one or more of the following: Ventricular tachycardia or fibrillation or aborted sudden death, preoperative cardiac massage, preoperative ventilation before arrival in the anaesthetic room, preoperative inotropic support,	3

	intraaortic balloon counterpulsation or preoperative acute renal failure (anuria or oliguria <10ml/h)	
Cardiac Related Factors Unstable angina	Rest angina requiring i.v. nitrates until arrival in the anaesthetic room	2
LV dysfunction	Moderate or LVEF 30-50% Poor or LVEF < 30%	1 3
Recent myocardial infarct	(<90 days)	2
Pulmonary hypertension	Systolic PA pressure >60 mmHg	2
Operation Related Factors Emergency	Carried out on referral before the beginning of the next working day	2
Other than isolated CABG	Major cardiac procedure other than or in addition to CABG	2
Surgery on thoracic aorta	For disorder of ascending, arch or descending aorta	3
Postinfarct septal rupture		4

(Nashef et al, 1999)

Similarly to the Parsonnet scoring system, the EuroSCORE is additive using incremental points; a score of 0-2 is considered low risk for predicted mortality; a score of 3-5 is medium risk and a score of greater than 6 is considered high risk.

The use of the EuroSCORE for cardiac operative risk evaluation has been consistently validated (Roques et al, 1999; Geissler et al, 2000; Nashef et al, 2002; Toumpoulis et al, 2004; Maria et al 2005; Cornelissen and Arrowsmith, 2006; Serag and Serag, 2007; Dupis, 2008) and demonstrates higher specificity than the Parsonnet's score (Serag and Serag, 2007). Although, the EuroSCORE has reasonable predictive ability, Bhatti et al (2006) argued that it can over predict risk in comparison with observed mortality.

Furthermore, the logistic EuroSCORE was introduced in 2003 (Roques et al, 2003). This centred upon a complex algorithm to derive risk from the same preoperative and operative risk factors. The logistic EuroSCORE was proposed to be a more superior predictor of operative risk in comparison to the additive model, which was evaluated by Bhatti et al in 2006. They concluded that the logistic EuroSCORE is a reasonable overall predictor for contemporary cardiac surgery, nevertheless overestimates observed mortality, and shows a variation in predicting risk in different surgical groups. The authors discuss an important issue surrounding the data on which the EuroSCORE was developed in the late 1990's, and highlight how surgical practice together with anaesthetic and intensive care advances have altered since that time. The authors question the accuracy of the data used and its application to the current surgical population. Currently, the logistic EuroSCORE is employed by consultant surgeons at the cardiac centre at ABMU. The statistical algorithm is available at: www.euroscore.org/logisticEuroSCORE.htm (EuroSCORE, 2003).

1.7.1 National Adult Cardiac Surgery Audit

As a platform for quality performance evaluation, all NHS cardiac surgery centres are required to submit data to the National Adult Cardiac Surgery Audit. The National Institute for Cardiovascular Outcomes Research (NICOR) at the University College, London, analyses the data submitted by NHS clinicians surrounding heart disease, quality of care and outcomes (NICOR, 2011). This mandatory audit process was in response to the National Service Framework (NSF) for Coronary Heart Disease (2000) which centered upon the prevention, diagnosis and treatment of heart disease. This NSF set out milestones for a 10-year period which included the mandatory requirement for audit and specifically defines the number of CABG surgery performed by each surgeon, in each centre, in addition to the risk adjusted number and percentage mortality after CABG at each institution, to be recorded (Department of Health, 2000; Keogh and Kinsman, 2004). The obligation to continuously collate this data as a method for evaluation of quality performance continues to the present day.

In collaboration with NICOR, the SCTS publishes National Adult Cardiac Surgical Database Reports surrounding surgical activity and mortality data (Bridgewater et al, 2008) .To date, the reports have displayed a decreasing trend towards operative mortality rates for all major cardiac procedures, despite patients being perceived to be sicker. From 2001 to 2008, the 6th National Adult Cardiac Surgical Database Report demonstrated the mortality rates for all CABG surgery to have significantly fallen from 2.6% to 1.7%; 5.2% to 3.5% for isolated valves, and 8.3% to 6.1% for combined CABG and valve surgery (Bridgewater et al, 2008). In the more recent published annual report by NICOR (2011), the mortality outcomes are continuing to demonstrate this trend, reporting mortality rates of 1.5% for an isolated CABG, 1.8% for an isolated valve and 3.6% for concomitant surgery in 2010.

Although the sophisticated data available from the SCTS reports provide a valuable insight into surgical activity and outcomes, the risk stratification models providing a percentage risk of 30-day mortality, portray only one element of the investigation. The prediction of adverse outcome following cardiac surgery is just as valuable. Major morbidity and prolonged postoperative length of intensive care stay are also important outcomes in the planning for the cardiac surgical patient including the allocation of resources (Maria et al, 2005). An association between prolonged postoperative ICU stay as a strong predictor of long term outcome together with the EuroSCORE was found by Maria et al (2005).

1.8 Government Initiatives

In aspiring to meet the needs and challenges of the 21st Century, Dr. Brian Gibbons, former Minister for Health and Social Care for Wales, emphasised the prudent requirement to 'create world class health care and social services in a healthy, dynamic country by 2015'. Subsequently the Welsh Assembly Government (WAG) embarked on a major programme of reform, the 'Designed for Life' Strategy in 2005.

In recognition of this objective, 'Design for Life' introduced the 'Quality Requirement for Adult Critical Care in Wales'. In managing Critical Care Service Delivery section of this report, it reviewed the provision of services by the Multi-Disciplinary Team. A report publication by Emergency Pressure Taskforce Group in 2000, demonstrated there to be a deficit in the number of adult intensive care beds in Wales. Additionally, an Audit Commission 'Critical to Success' review (Audit Commission, 1999) was conducted and this proposed that there should be 5 levels of Critical Care. ABMU Tertiary Cardiac Services fall into level 3T (Tertiary) allowing all key personnel to review its fundamental quality requirements. In striving towards achieving these quality requirements, the role of the Physiotherapist in Critical Care includes the delivery of appropriate respiratory care, maximising the patient's respiratory potential, to facilitate weaning and extubation from artificial ventilation and likewise to prevent reintubation (Welsh Assembly Government, 2006).

Additionally, when reviewing the contribution of Therapy Service in the delivery of Health and Social Care in Wales, 'A Therapy Service Strategy for Wales' was subsequently created. This vision strengthens the 'The Health and Social Care Review for Wales' report written by Sir Derek Wanless in 2003, and sets out key roles and objectives for therapy staff to focus upon. The principles advocate health promotion, early intervention strategies to facilitate the rate of recovery and limit further deterioration and the avoidance of the development of chronic conditions. Furthermore, it promotes the use of the Multi-Disciplinary Team approach to improve the provision of assessment, strengthening pre-admission and accelerated discharge schemes (Welsh Assembly Government, 2006). As a consequence, there is a demand and expectation upon clinicians to continuously evaluate the services accordingly, from a clinical effectiveness and efficiency standpoint to ensure high levels of patient care.

1.9 Physiotherapy Services

Currently, within the delivery of modern day intensive care medicine, the provision of Physiotherapy treatment is considered an integral component in ensuring optimal patient care and clinical success. Chest Physiotherapy (CPT) is a collective term that is used to describe a variety of treatments that are delivered to patients in an attempt to restore, improve or maximise pulmonary function. Currently, a variety of patient populations receive CPT such as surgical patients following abdominal, cardiac or thoracic surgery, together with patients with neurological, circulatory or respiratory impairment.

Recently, Overend et al (2010) acknowledged how the provision of optimal physiotherapy care for patients undergoing cardiac surgery was not well established, structured or completely understood. Additionally, the authors highlighted that the historical practice of a preoperative assessment and postoperative treatment until discharge is now being questioned and requires further exploration. For example, it is proposed that potentially not all patients may require this traditional clinical management protocol and argued that such approaches consume valuable physiotherapeutic resources (i.e. staff, time and expertise), and perhaps this resource utilisation is not conducted in the most effective or efficient way.

In light of this and in the absence of current systematic reviews of optimal physiotherapy care at the time, it was decided by Overend et al (2010) to conduct a survey of practice. The aim was to determine current physiotherapy practice for adult patients requiring routine care after undergoing CABG surgery and/or valve surgery. Based in Canada, a telephone survey was conducted across 18 hospital sites where cardiac surgery was performed. Their survey investigated current practice in relation to cardiorespiratory assessment and treatment on postoperative days 1-3, mobilisation, upper and lower extremity exercise, sternal precautions, lifting precautions, education and discharge teaching. Their results demonstrated only 40% reported seeing patients preoperatively, however 90% of those surveyed assess and treat patients on the first postoperative day. Following this, there is a reduction in the provision of physiotherapy assessment to 60% and treatment to 50% by the third postoperative day. Treatment techniques primarily consisted of deep breathing exercises and coughing, incentive spirometry, mobilisation and education. Further along, there was an evident shift in focus of physiotherapy treatment towards mobilisation and education and less towards pulmonary concerns. Whilst this study provides an overview of physiotherapy practice, there was no mention of identifying patients at risk of developing pulmonary complications following surgery. It is also not explicitly stated whether patients were treated during the time of intubation and ventilation or just following extubation, as the results were grouped together.

In comparison, Reeve and Ewan conducted a similar survey of practice in the U.K in 2005. Using a mailed questionnaire, the senior physiotherapists in all cardiothoracic units in the UK (n=52) were surveyed. A response rate of 80% (n=40) was obtained. Those respondents provided information relating to the assessment and treatment programmes for preoperative and postoperative management of patients that undergo routine coronary artery bypass surgery. The results showed that 58% (n=23) of respondents saw patients preoperatively, 20% (n=8) report to treat patients whilst intubated and ventilated, and 95% provided assessment and treatment following extubation. Interestingly, 72.5% (n=29) units had no specific physiotherapy protocols for the immediate postoperative practice, suggesting that physiotherapy during this timeframe is not routine practice in the units surveyed at that time. In addition to the assessment of physiotherapy provisions, the authors explored the respondent's awareness of the available evidence in the physiotherapy management of the routine CABG patient. From the survey, 70% of the physiotherapists indicated their knowledge of the literature, together with personal experience and established protocols within their service, affected their preoperative practice despite there being a lack of evidence within the literature at the time to support their practice. However, the authors discuss a rationale to highlight patients deemed "high risk" preoperatively to direct the selection of the necessary patients. It is felt that the results also demonstrated that the prophylactic postoperative physiotherapy is provided to the patients at the units surveyed despite the lack of supportive literature. This is proposed to be governed by personal preference and established practice, and a reluctance to change practice based on the available literature was apparent. The authors advocate that physiotherapists should use their awareness of the evidence to modify or even discontinue treatments found to be ineffective, and promote a shift in focus to identifying those patients who are at greatest risk for the development of PPC's.

In an earlier study, when examining the provision of physiotherapy for patients undergoing coronary artery surgery in Australia and New Zealand, Tucker et al (1996) adopted a similar approach and conducted a questionnaire survey. A total of 42 hospitals participated in the study, in which a senior physiotherapist provided information on their assessment and treatment techniques. In addition to this, the criteria used to identify high-risk patients for the development of PPC's were examined.

The results showed 94% of respondents provided routine preoperative assessment, which is vastly greater than reported by Overend et al (2010) and Reeve and Ewan

(2005) and 89% of physiotherapists routinely treated patients in the post-extubation period. In this study, the most commonly used techniques were positioning and deep breathing exercises.

With regards to the preoperative assessment, 94% of respondents identified patients who were believed to be at an increased risk for the development of PPC's, a notion that has been later promoted in the UK based study conducted by Reeve and Ewan (2005). The basis on which patients were determined as high risk were dependent on four frequently cited high risk criteria; pre-existing pulmonary dysfunction or disease (all respondents), smoking history (94%), pre-existing mobility/neurological disorder (88%) and body weight (82%). Other factors also identified were increased age (73%), complications following a previous general anaesthetic (67%) and unstable psychoemotional status (48%). Although the authors report that some of the frequently cited risk factors are reported as potential risk factors within the literature, and some remain questionable, the authors fail to confirm the basis on which the physiotherapists determine high risk, for example, are their assessment criteria based on evidence of personal experience? This was not clarified. However, any studies into physiotherapy practice to determine if patients are predisposed to PPC's appear scarce.

In relation to the immediate postoperative period, 63% of respondents identified a specific protocol for respiratory management of patients whilst intubated and ventilated. The treatment techniques utilised were manual hyperinflation and suctioning, however, the authors report that data on the treatment of patients that were intubated were limited due to an unforeseen error in the questionnaire. However, no comparisons can be directly made to the equivalent study by Overend et al (2010), as their results were not separated into treatments performed whilst patients were intubated or extubated. Although the units providing routine treatment for patients whilst intubated and ventilated is considerably greater than that reported by Reeve and Ewan (2005).

As previously stated by Overend et al (2010), the three surveys discussed provide a valuable overview of physiotherapy practice across 3 regions, over a 12 year period, from which worthwhile comparisons could be made.

Other systematic reviews undertaken into physiotherapy services within cardiac surgery by Pryor (1999); Pasquina et al (2003); Miranda et al (2011); Hulzebos et al (2012) have confirmed the evidence surrounding physiotherapy is variable and remains conflicting and unproven. The physiotherapy evidence will be examined further in the narrative review of postoperative complications and physiotherapy practice following cardiac surgery in chapter 3.0.

Within ABMU Cardiac Centre, CPT is routinely delivered as part of current practice to all patients in the CITU following their surgery and once the patients are extubated following the initial period of mechanical ventilation. CPT is provided at this time and in the following concurrent postoperative days with the aim of treatment to remove bronchial secretions and thus the avoidance of respiratory infection and the re-inflation of atelectic segments within the lung fields whilst increasing tidal volumes. The most common techniques include deep breathing exercises, forced expiratory technique (FET), supported coughing, manual techniques, positioning to optimise ventilation/perfusion ratio and early ambulation. For those patients who fail to be extubated, the CPT provided utilises treatments such as manual hyperinflation, suctioning and manual techniques. The physiotherapy treatment regimens have been exhaustively researched and yet remain conflicting (Hulzebos, 2003); promoting such treatments to have been demonstrated to improve basal ventilation (Brasher 2003) and increase tidal volumes (Webber and Pryor, 1993) and yet, evidence has been documented to indicate that they do not to significantly alter patient outcomes (Brasher, 2003).

In accordance with the Chartered Society of Physiotherapy Standards (CSP, 2013) following a thorough assessment of a patient, a treatment plan is devised based on the best available evidence to deliver effective care (CSP, 2013). This is an expectation of the professional governing body in assuring quality standards (CSP, 2013). Subsequently, the selection of which treatments are indicated or contraindicated, the frequency and duration of treatments required are based upon astute clinical reasoning skills and evidence based practice. This system enables a clinician to continually re-assess a patient throughout their pathway of care in order to avoid the development of PPC's. However, currently at ABMU cardiac centre it is not routine clinical practice within physiotherapy to carry out a preoperative screening assessment to identify those patients at risk for the development of PPC's following surgery.

1.10 Post-Operative Pulmonary Complications

Although there are continually advancing practice within Cardiac Surgery, serious complications will certainly remain. A cardiac surgical procedure is highly technical and thought to expose the respiratory system to an array of potential injuries and stresses (Adair and Kon, 1994). The development of PPC's in patients undergoing Cardiac Surgery utilising hypothermic CPB has been well recognised (Weissman, 2000; Ng et al, 2002; Andrejaitiene et al, 2004; Dixon et al, 2008; Kerendi et al, 2011). Postoperatively, the presence of pulmonary abnormalities such as atelectasis has a reported incidence of up to 65% (Pasquina et al, 2003) and pneumonia is thought to occur in 3 to 16% of patients (Weissman, 2000). The clinical manifestations range from a productive cough to respiratory failure with hypoxemia and the requirement for mechanical ventilation (Weissman, 2000; Ng et al, 2002; Wynne and Botti, 2004).

To evaluate the frequency and severity of respiratory dysfunction after uncomplicated CPB, Taggart et al (1993) compared 129 patients who underwent isolated coronary artery bypass grafting (Group 1) to 30 general surgery patients (Group 2). To quantify the incidence and severity of dysfunction, arterial oxygen tension (Pao2), alveolar-arterial oxygen gradient (Aao2) and the percentage pulmonary shunt fraction (%PSF) were used as outcomes measures. Data was collected preoperatively, and on the first, second and sixth postoperative days. To determine the duration of respiratory dysfunction after cardiac surgery, measurements were continued until the sixth postoperative week for 30 patients (Group 3). The sample cohort had no clinical evidence of respiratory or cardiac impairment and were therefore considered low risk. Furthermore, those who underwent cardiac surgery were extubated usually 10 to 12 hours following their surgery, which differs to clinical practice today. Their results showed those patients undergoing cardiac surgery had a marked reduction in Pa02 from preoperatively to the second postoperative day ($p<0.001$), and with a modest improvement by day 6, in comparison to those who underwent general surgery, who had also displayed the same trend, although this was less severe and showed a return to the baseline values by day 6. Those individuals followed up until the sixth postoperative week demonstrated a similar decline in respiratory dysfunction early on following their surgery, nevertheless had a complete resolution by the sixth week, at follow up. Taggart et al (1993), demonstrated that respiratory dysfunction even following an uncomplicated CPB is common, and the degree of impairment is significant even in low-risk patients, however is completely resolved within 6 weeks. It is important to note that the authors acknowledge how the incidence and severity of respiratory dysfunction may differ in patients who are considered high risk.

In the absence of evidence based clinical guidelines on the management of postoperative pulmonary dysfunction after cardiac surgery, Wynne and Botti (2004) and others reviewed the pathophysiological basis of the development of PPCs. They postulated a variety of surgical based factors, in addition to the risk factors previously mentioned that are thought to be associated with the pathogenesis of pulmonary dysfunction postoperatively.

Primarily, a general anaesthesia in combination with a prolonged supine position during surgery elevates the diaphragm in addition to altering the compliance of the chest wall. However, this creates a ventilation-perfusion mismatch by the shifting of the blood from the abdomen to the thorax (Wynne and Botti, 2004). As a consequence of this, pulmonary function parameters such as Vital Capacity (VC) and Functional Residual Capacity (FRC) are reduced by as much as 20% (Van Belle et al, 1992; Brasher, 2003; Wynne and Botti, 2004). Subsequently, the chest wall motion and respiratory mechanics are thought to be considerably affected by cardiac surgery for up to three months postoperatively (Kristjansdottir et al, 2004).

Secondly, the surgical approach and the nature of the cardiac procedure poses a threat to pulmonary mechanics, depressing cardiac function and the handling of thoracic contents, impairs pulmonary gaseous exchange (Weissman, 2000). In particular, during CABG surgery, following a median sternotomy incision, the internal mammary artery is harvested. However, associated with the harvesting of this vessel involves breaching the pleural space and inserting a chest drain, thus patients are susceptible to postoperative pulmonary impairment (Matsumoto et al, 1997) with a reduction in spirometric tests i.e. VC and FEV1 (Rolla et al 1994). Additionally, patients are thought to encounter considerable chest trauma during cardiac surgery (Weissman, 2000). According to Adair and Kon (1994), valve surgery produces comparable reduction in lung volumes following surgery.

The pathogenesis of pulmonary dysfunction associated with the effects of the CPB circuit has also been consistently documented. CPB is proposed to be a causative factor for the development of postoperative pulmonary dysfunction; the clinical features are unmistakable, from arterial hypoxaemia, atelectasis to acute lung injury. This dysfunction is referred to as "post-pump lung". CPB is thought to generate acute systemic and pulmonary inflammatory reactions (Westaby, 1983; Wynne and Botti, 2004; Zupancich et al, 2005) such as increased lung permeability and pulmonary vascular resistance in addition to affecting surfactant activity. This is proposed to be attributable to the initial stages of lung injury following CPB (Rady et al, 1997; Ng et al, 2002).

Although, a prospective randomised study undertaken by Cox et al (2000) in which 52 patients were randomised into 2 groups, a "CPB group" and a Non-CPB group"; all patients that were enrolled underwent elective CABG surgery with the aim of determining the effect of CPB on pulmonary gas exchange. They excluded patients with known pulmonary disease, smoking within 6 months prior to surgery, poor left ventricular function, recent myocardial infarction (MI) and reoperation. The results showed no significant difference as assessed by alveolar-arterial oxygen gradients between the two groups, suggesting that the deterioration in pulmonary gas exchange would be due to other factors than the CPB.

More recently, in 2004, Andrejaitiene et al found statistically significant differences between two groups of patients that underwent cardiac surgery utilising CPB and another group without CPB. Blood gas analysis measured the level of intrapulmonary shunt as a determinant of pulmonary function and evidence of atelectasis on CXR confirmed that patients undergoing cardiac surgery with CPB had a greater pulmonary dysfunction following surgery.

In an assessment of patients undergoing cardiac surgery with CPB, Rodrigues et al (2011) employed computed tomography (CT) to evaluate the changes in lung structure. Eighteen non-hypoxemic patients with normal cardiac function were studied. Compared to preoperative CT scans, the results showed a 24% postoperative increase in the amount of collapsed lung tissues and a significant decrease in the pulmonary gas volume ($p<0.001$). This data has displayed profound changes within the lung structure that occurs after CABG with CPB (Rodrigues et al 2011).

Furthermore, in relation to standard operative procedures for cardiac surgery, as previously discussed, a key component involves the cross clamping of the aorta, as lung ventilation and circulatory arrest occur during the induced hypothermia stage. This is thought to be a further source of postoperative pulmonary dysfunction (Talay et al, 2011).

Other acknowledged contributory factors for the development of PPC's include phrenic nerve paralysis or dysfunction which is associated with the use of myocardial topical cooling for myocardial protection. Consequently, this lowers the Vital Capacity resulting from cardiopulmonary ischaemia and lung ventilatory arrest (Estenne et al, 1985; Engoren et al, 1999; Ng et al, 2002; Wynne and Botti, 2004). Phrenic nerve injury resulting in diaphragmatic dysfunction has been suggested to contribute to partial or complete recurrent lung collapse following cardiac surgery (Zaky et al, 2009).

There is, therefore, a prudent need to further examine the nature of PPC's and to explore physiotherapy strategies to minimise pulmonary complications. It could be argued that without effective interventions to reduce the development of PPC's, prolonged mechanical ventilation remains a threat, thus giving rise to a prolonged intensive care stay and significant consumption of healthcare resources. This poses a greater risk of morbidity and mortality following adult cardiac surgery (Weissman, 2000), and the strive towards the rapid recovery management is diminishing.

1.11 Summary

The information contained within the introductory chapter has outlined the knowledge and evidence relevant to the context of the overall thesis. In order to address the aims of the project, the subsequent chapters are summarised below:

- Chapter 2 will include a systematic review of the preoperative characteristics or risk factors for the development for PPC's following adult cardiac surgery. This will assist in understanding the nature and potential causal factors of PPC's.
- Chapter 3 is a narrative review of the literature examining postoperative complications in particular PPC's, in determining morbidity and mortality which will expand on the understanding of PPC's in the wider context. The role of physiotherapy strategies in addressing PPC's will also be examined in the narrative review. This knowledge is paramount to inform physiotherapy practice locally.
- Chapter 4 describes the planning process of undertaking a service evaluation and provides a conceptual and theoretical framework to evaluate cardiothoracic surgical services at ABMU, cardiac centre.
- Chapter 5 includes a service evaluation of cardiothoracic surgical services at the ABMU, cardiac centre. The local cardiac surgical population will be described,

the incidence of PPC's will be determined and the impact of PPC's on clinical outcomes will be examined.

- Chapter 6 will review the components of the project, together with discussing the findings in addressing the overall aim of the thesis. The findings will also be compared to the body of evidence. The potential opportunities for physiotherapy strategies to avert PPC's and thus informing physiotherapy practice will be deliberated. Additionally the suggestions for future work in this area will be presented.
- Chapter 7 is the conclusion chapter to this programme of research.

It is hoped that the results generated from this research will provide a greater understanding into PPC's following cardiac surgery and an insight into basic trends over the data collection period. This information will allow a comparison to be made with the current body of literature and an opportunity to compare the local population to that at a national level. Secondly, the information generated from this programme of research will provide a greater understanding into the patients that undergo cardiac surgery today. Furthermore, this will be an essential foundation to informing physiotherapy clinical practice. The introduction of strategies or developments, including the feasibility of predicting those patients at greater risk as well as strategies to reduce the incidence of PPC's, within this specialty in the near future will be considered. The next chapter will examine the literature surrounding preoperative patient characteristics or risk factors for the development of PPC's following cardiac surgery.

2.0 Systematic Review

Preoperative Patient Characteristics and Risk Factors for the Development of PPC's Following Cardiac Surgery

2.1 Introduction

2.1.1 Rationale

As mentioned in Chapter 1.0, within the U.K it is estimated that approximately 30, 000 adult patients will undergo a cardiac surgical procedure, annually (NICOR, 2011). Over recent years the demand for open heart surgery has risen, which is mainly attributable to advances within interventional cardiology procedures (Weissman, 2004). Subsequently, there is a larger proportion of patients that now require cardiac surgery with more advanced disease (Ferguson et al, 2002) and the profile of the cardiac surgical patient has altered (Ferguson et al, 2002). Cardiac surgery is undertaken on older, more frail patients that have pre-existing co-morbidities (Ferguson et al, 2002; Canver and Chanda, 2003; Hulzebos et al, 2006). Consequently, postoperative morbidity has increased (Ghotkar et al, 2006).

The development of PPC's in patients undergoing cardiac surgery utilising hypothermic cardiopulmonary bypass has been well recognised (Ng et al, 2002; Wynne et al, 2004; Weissman, 2004; Poelaert and Roosens, 2009). The impact of PPC's on mortality and morbidity rates has been consistently documented (Ng et al, 2002; Wynne et al, 2004; Poelaert and Roosens, 2009).

Numerous risk factors for the development of PPC's have been proposed through extensive research into this area utilising multivariate analysis of risk factors (Cohen et al, 1995; Arom et al, 1995; Rady et al, 1997; Engoren et al, 1999; Ferguson et al, 2002; Hulzebos et al, 2003; Weissman et al, 2004). Despite this, and the various prediction models available to yield operative mortality figures or to predict the duration of intensive care stay i.e. Parsonnet and EuroSCORE, there is less consensus surrounding predictive characteristics for the development of PPC's following cardiac surgery.

In order to address this, a review of the specific risk factors and preoperative characteristics and their influence on the pulmonary complications proposed is necessary to gain a superior understanding into this complex problem. With the aim of developing more effective physiotherapy strategies for managing pulmonary complications, a review of preoperative risk factors that can identify those individuals deemed at greater risk, is a crucial step in understanding and managing PPC's. Additionally, it will assist in the process of identifying key patient characteristics to be extracted from clinical records as part of the service evaluation audit used in this programme of research.

2.1.2 Aim

The aim of this chapter is to explore the research evidence relating to the risk factors for the development of PPC's and to ascertain if any prediction model exists within the literature that could be used to inform physiotherapy practice in the future.

2.1.3 Objective

The objective of this review is to undertake a systematic review to critically appraise the research evidence relating to the risk factors for the development or prediction of PPC's within the existing evidence base. Additionally it will contribute to the current database of knowledge within this domain by updating with the studies recently undertaken, particularly those studies that could assist with the development of physiotherapy services.

2.1.4 Research Question

What is the level of empirical evidence to identify risk factors for the development of PPC's following cardiac surgery?

2.2 Methodology

2.2.1 Identification

In order to identify the relevant literature relating to postoperative pulmonary complications following adult cardiac surgery including risk factors, patient characteristics and prediction models, a number of methods were employed.

Electronic searches, hand searches and a quality criterion were employed to undertake a rigorous and comprehensive search of the literature available and relevant peer-reviewed literature was also collated and reviewed for relevance to the overall discussion.

2.2.2 Search Strategy and Electronic Searches:

A preliminary search of the literature was undertaken to highlight key phrases to facilitate the development of key words and mesh terms necessary for the detailed categorical search, these included:

- Cardiac Surgery
- Postoperative Respiratory or Pulmonary Complications
- Patient Characteristics
- Patient Screening
- Risk Factors
- Length of Stay

An extensive search was then carried out through the following databases:

- Medline
- EMBASE
- AMED
- Cumulative Index to Nursing and Allied Health (CINAHL)
- PubMed
- Web of Knowledge

Due to the large numbers of papers retrieved from the databases, the searches were limited to studies of human and adult subjects, restricted to English language and those studies published in the last 20 years. The key words or mesh terms were individually searched and then combined in order to locate the most relevant literature.

The same process (i.e. combining key words and limiting searches) was conducted on all of the electronic databases between the search dates of 1993 and 2013. The last search was undertaken on 18 April, 2013. The results of the electronic search strategy displaying the number of papers retrieved from each database are shown in Table 6, together with the key words, mesh terms and combinations.

In the interest of clarity, after the main aspect of the search was undertaken, i.e. exploring cardiac surgery and respiratory complications, the search strategy was then deducted into three sub-sections. This was necessary to address the objectives of the project. Therefore, the search strategy displays the sub-sections as additional searches, the focus of which is summarised below:

Search a) exploring prediction models or risk strategies

Search b) Patient characteristics or preoperative risk factors

Search c) Clinical outcomes i.e. length of stay in intensive care

2.2.3 Screening

The citation and abstract of the papers yielded by the search were read and appraised in order to confirm their eligibility for inclusion within this review. This ensured that the papers included were relevant to the overarching objective of this project.

2.2.4 Inclusion Criteria:

Papers were included in the review if they were published within the dates identified of 1993 to 2013, if the full text of the paper was available, and the research was evidence relating to risk factors for the prediction of PPC's following cardiac surgery and within the context of the overall aim of the project.

Hand Searching

The reference lists of the relevant studies found through the electronic database searched were then checked for further relevant papers.

2.2.5 Eligibility and Inclusion

Quality Criterion

In determining a suitable quality criterion that could be utilised to screen the literature for inclusion within this review, several options were explored.

PEDro is a physiotherapy evidence database that consists of randomised trials, systematic review and clinical practice guidelines for physiotherapy *(PEDro, 1999)*. The PEDro quality scoring scale has been studied for its reliability of rating quality of randomised controlled trials of physiotherapy evidence (*de Morton, 2009).* Although the PEDro scale is a validated scoring system, it was deemed unsuitable for this review as it would not reflect the nature of the studies yielded.

CONSORT, which represents Consolidated Standards of Reporting Trials *(CONSORT, 2010)* that is based upon recommendations for reporting randomized trials. The CONSORT statement checklist was reviewed and discounted due to its main focus being heavily based on clinical trials.

The 'CASP' Critical Appraisal Tool was identified and then reviewed for its suitability for the appraisal of the papers identified in the review. CASP represents Critical Appraisal Skills Programme, and provides a practical framework to undertake the appraisal of information, ensuring that health decisions are informed by the best available evidence. Following a Set of critical appraisal tools facilitates a systematic approach to examine the research to assess its validity and reliability and by extension considering its relevance in a particular context thus informing healthcare decisions (Critical Appraisal Skills Programme, 2010).

The 'CASP' checklist consists of partitioned checklist of 12 conditions, with a possible total score of 10 if all 12 conditions are fulfilled. Criteria 1 to 6, (Part A) assesses the internal validity of a study and is a score out of 8. Then, the results are assessed by criterion 7 to 9 (Part B), and is scored out of 1. Additionally, Criteria number 10 refers to the application of the findings to the local population (Part C), and is scored out of 1. Points are only awarded if a criterion is clearly satisfied and reported. Criteria 11 and 12 refers to the implications of the findings for practice and these items are not used to calculate the CASP score, but are included to consider the relevance of the findings within a healthcare context.

It was decided that CASP was appropriate scoring system to employ based upon its systematic approach to assessing the validity and reliability of the research and by extension its relevance to healthcare which would be extremely relevant in the current project. Thus the CASP critical appraisal framework would be used as the data extraction tool for this review.

Two reviewers, Mrs. Gemma Thomas, as the principal researcher for the project and Dr. Gareth Noble as the principal supervisor, scored the papers using the 'CASP' critical appraisal tool. Any variation within the scores were resolved in order to ensure there was an agreed consensus between the two reviewers. Papers were included if they yielded a combined score of 7 or above ensuring quality appraised studies were included in the review. The CASP Checklist together with the marking criteria with which papers were appraised is shown in Figure 3 below:

(Part A) Are the results of the study valid?

Screening Questions

1. Did the study address a clearly focused issue? **□Yes □Can't tell □No**

HINT: A question can be 'focused' In terms of
• The population studied
• The risk factors studied
• The outcomes considered
• Is it clear whether the study tried to detect a beneficial or harmful effect?

2. Was the cohort recruited in an acceptable way? ☐**Yes** ☐**Can't tell** ☐**No**

HINT: Look for selection bias which might compromise the generalisibility of the findings:
• Was the cohort representative of a defined population?
• Was there something special about the cohort?
• Was everybody included who should have been included?

Detailed questions

3. Was the exposure accurately measured to minimise bias? ☐**Yes** ☐**Can't tell** ☐ **No**

HINT: Look for measurement or classification bias:
• Did they use subjective or objective measurements?
• Do the measurements truly reflect what you want them to (have they been validated)?
• Were all the subjects classified into exposure groups using the same procedure

4. Was the outcome accurately measured to minimise bias? ☐**Yes** ☐**Can't tell** ☐**No**

HINT: Look for measurement or classification bias:
• Did they use subjective or objective measurements?
• Do the measures truly reflect what you want them to (have they been validated)?
• Has a reliable system been established for detecting all the cases (for measuring disease occurrence)?
• Were the measurement methods similar in the different groups?
• Were the subjects and/or the outcome assessor blinded to exposure (does this matter)?

5. (a) Have the authors identified all important confounding factors? ☐**Yes** ☐**Can't tell** ☐**No**

List the ones you think might be important, that the author missed.

(b) Have they taken account of the confounding factors in the design and/or analysis? List: ☐**Yes** ☐**Can't tell** ☐**No**

HINT: Look for restriction in design, and techniques e.g. modelling, stratified-, regression-, or sensitivity analysis to correct, control or adjust for confounding factors

6. (a) Was the follow up of subjects complete enough? ☐**Yes** ☐**Can't tell** ☐**No**

(b) Was the follow up of subjects long enough? ☐**Yes** ☐**Can't tell** ☐**No**
HINT: Consider
• The good or bad effects should have had long enough to reveal themselves
• The persons that are lost to follow-up may have different outcomes than those available for assessment

• In an open or dynamic cohort, was there anything special about the outcome of the people leaving, or the exposure of the people entering the cohort?

(Part B) What are the results?

7. What are the results of this study?

HINT: Consider
• What are the bottom line results?
• Have they reported the rate or the proportion between the exposed/unexposed, the ratio/the rate difference?
• How strong is the association between exposure and outcome (RR,)?
• What is the absolute risk reduction (ARR)?

8. How precise are the results?

HINT: Look for the range of the confidence intervals, if given.

9. Do you believe the results? ☐**Yes** ☐**Can't tell** ☐**No**

HINT: Consider
• Big effect is hard to ignore!
• Can it be due to bias, chance or confounding?
• Are the design and methods of this study sufficiently flawed to make the results unreliable?
• Bradford Hills criteria (e.g. time sequence, dose-response gradient, biological plausibility, consistency)

(Part C) Will the results help locally?

10. Can the results be applied to the local population? ☐**Yes** ☐**Can't tell** ☐**No**

HINT: Consider whether
• A cohort study was the appropriate method to answer this question
• The subjects covered in this study could be sufficiently different from your population to cause concern
• Your local setting is likely to differ much from that of the study
• You can quantify the local benefits and harms

11. Do the results of this study fit with other available evidence? ☐**Yes** ☐**Can't tell** ☐**No**

12. What are the implications of this study for practice?

Figure 3: CASP Checklist (CASP, 2010)

2.3 Results

2.3.1 Search History

The table below (Table 6) displays the search history and shows the number of papers yielded, with each keyword and their combinations, from Medline, Embase, AMED, British Nursing Index (BNI), CINAHL, PubMed and Web of Knowledge databases, between the search dates of 1993 and 2013.

Table 6: Search History

Search	Keywords	Database	No of Hits	No of papers identified
1	Cardiac surgery/	**Medline**	2363	
2	Cardiac surgical procedures/		19 608	
3	Coronary artery bypass/		24 991	
4	Cardiopulmonary bypass/		12 313	
5	Heart valves.mp		4 047	
6	Aorta, thoracic/		13 458	
7	#1 or #2 or #3 or #4 or #5 or #6		69 503	
8	Applied Limits		32 405	
9	Postoperative complications/		128 668	
10	Respiratory complications.mp		1601	
11	Respiratory tract diseases/		6596	
12	Respiration disorders/		3133	
13	Pulmonary atelectasis/		1496	
14	Pneumonia/		13 350	
15	Postoperative pulmonary complications.mp		383	
16	#10 or #11 or #12 or #13 or #14 or #15		25 868	
17	#9 AND #16		1282	
18	Applied Limits		679	
19	# 8 AND #18		**77**	
20	Risk assessment/		148 053	
21	Risk/		37 390	
22	Preoperative period/ OR Preoperative care/		26 486	
23	Preoperative screening.mp		373	
24	Prediction.mp		83 712	
25	#20 OR #21 OR #22 OR #23 OR # 24		285 970	
26	Applied Limits		124 579	
27	#19 AND #26	*SEARCH A*	**16**	**10**
28	Risk factors/		415 861	
29	Patient characteristics.mp		11 487	
30	#28 OR #29		425 439	

31	Applied Limits		227 663	
32	#19 AND #31	*SEARCH B*	**24**	**19**
33	Length of stay/ OR length of stay.mp		47 163	
34	Intensive care unit/ OR Intensive care/		32 067	
35	ICU stay.mp		2701	
36	#33 OR #34 OR #35		75 262	
37	Applied Limits		40 803	
38	#19 AND #37	*SEARCH C*	**28**	**18**
39	#1	**EMBASE**	62 122	
40	#2		62 122	
41	#3		51 831	
42	#4		29 487	
43	#5		5809	
44	#6		17 424	
45	#7		151 395	
46	#8		79 276	
47	#9		251 69	
48	#10		3525	
49	#11		39 137	
50	#12		5837	
51	#13		10 371	
52	#14		96 816	
53	#15		964	
54	#16		150 746	
55	#17		6612	
56	#18		4405	
57	#19		**338**	
58	#20		309 824	
59	#21		245 135	
60	#22		58 404	
61	#23		755	
62	#24		323 600	
63	#25		890 999	
64	#26		573 767	
65	#27 (+ Excluding Medline Journals)	*SEARCH A*	**10**	**4**
66	#28		569 245	
67	#29		21 038	
68	#30		587 989	
69	#31		418 573	
70	#32 (+ Excluding Medline Journals)	*SEARCH B*	**7**	**4**
71	#33		82 588	
72	#34		142 298	
73	#35		5962	
74	#36		212 296	
75	#37		140 238	
76	#38 (+ Excluding Medline Journals)	*SEARCH C*	**11**	**5**
77	#1	**AMED**	0	
78	#2		0	
79	#3		117	

80	#4		0	
81	#5		29	
82	#6		0	
83	#7		146	
84	#8		110	
85	#9		687	
86	#10		47	
87	#11		0	
88	#12		631	
89	#13		0	
90	#14		115	
91	#15		22	
92	#16		801	
93	#17		12	
94	#18		9	
95	#19		0	
96	#20		0	
97	#21		2503	
98	#22		203	
99	#23		0	
100	#24		1242	
101	#25		3901	
102	#26		3299	
103	#27	*SEARCH A*	0	
104	#28		784	
105	#29		304	
106	#30		1087	
107	#31		1029	
108	#32	*SEARCH B*	0	
109	#33		880	
110	#34		33	
111	#35		17	
112	#36		923	
113	#37		869	
114	#38	*SEARCH C*	0	
115	Heart Surgery (MM)	**CINAHL**	3 271	
116	Cardiac Surgical Procedures (TX)		64	
117	Coronary Artery Bypass (MH)		6 279	
118	Cardiopulmonary Bypass (MW)		2 298	
119	Heart Valves (TX)		669	
120	**"Aorta, Thoracic" (MH)**		856	
121	#115OR#116OR #117OR #118OR #119OR #120		12 250	
122	Postoperative Complications (MH)		19 995	
123	Respiratory Complications (TX)		342	
124	**"Respiratory Tract Diseases" (MH)**		1 882	
125	Respiration Disorders (MH)		1 424	
126	Atelectasis (MH)		455	
127	Pneumonia (MH)		4 639	

128	Postoperative Pulmonary Complications (TX)		126	
129	#123 OR #124 OR #125 OR #126 OR #127 OR #128		8 598	
130	#122 AND #129		402	
131	#121 AND #130		48	
132	Risk Assessment (MH) OR RISK (TX)		294 998	
133	Preoperative Period (MH)		984	
134	Preoperative Care (TX) OR Prediction (TX)		17 452	
135	#132 OR #133 OR #134		307 954	
136	#131 AND #135	*SEARCH A*	25	
137	Risk Factors (MH)		56 336	
138	Patient Characteristics (TX)		3 126	
139	#137 OR #138		59 242	
140	#131 AND #139	*SEARCH B*	1	
141	Length of Stay (MH) OR Length of Stay (TX)		17 813	
142	**"Intensive Care Units" (MH)**		14 314	
143	Critical Care (MH)		9 066	
144	ICU Stay (TX)		607	
145	#141 OR #142 OR #143 OR #144		36 710	
146	#131 AND #145	*SEARCH C*	14	
147	Applied Limits +Excl.Medline to #136,#140,#146			**2**
148	Cardiac surgery (MeSH Major Topic)	**PubMed**	122 475	
149	Cardiac surgical procedures (MeSH Major Topic)		115 596	
150	Coronary artery bypass (MeSH Major Topic)		299 74	
151	Cardiopulmonary bypass (MeSH Major Topic)		109 08	
152	Heart valves (Text Word)		8141	
153	Aorta, thoracic (MeSH Major Topic)		128 09	
154	#148 or #149 or #150 or #151 or #152 or #153		149 974	
155	Applied Limits (& Retained)		52 379	
153	Postoperative complications (MeSH Term)		116 815	
154	Respiratory complications (Text word)		793	
155	Respiratory tract diseases (MeSH Major Topic)		177 832	
156	Respiration disorders (MeSH Major Topic)		23 492	
157	Pulmonary atelectasis (MeSH Major Topic)		383	
158	Pneumonia (MeSH Major Topic)		9363	
159	Postoperative pulmonary complications (text)		261	
160	#154 or #155 or #156 or #157 or #158 or #159		178 394	
161	#153 AND #160		6062	
162	#155 AND #161		552	

163	Risk assessment (MeSH Term)		71 653	
164	Risk (MeSH Term)		333 458	
165	Preoperative period/ OR Preoperative care/		21 735	
166	Preoperative screening		41 838	
167	Prediction (Text Word)		29 898	
168	#162 OR #164 OR #165 OR #166 OR #167		146 921	
169	#162 AND #168	*SEARCH A*	85	**24**
170	Risk factors (MeSH Term)		239 631	
171	Patient characteristics (Text Word)		9090	
172	#170 OR #171		247 114	
173	#162 AND #172	*SEARCH B*	107	**23**
174	Length of stay (MeSH) OR length of stay (Text)		32 581	
175	Intensive care unit (MeSH) OR Intensive care		7102	
176	ICU stay (Text Word)		2087	
177	#174 OR #175 OR #176		38 811	
178	#162 AND #177	*SEARCH C*	61	**18**
179	Cardiac Surgery	**Web of Knowledge**	154 718	
180	Cardiac Surgical Procedures		41 847	
181	Coronary Artery Bypass		87 838	
182	Cardiopulmonary Bypass		54 653	
183	Heart Valves		97 044	
184	Thoracic Aorta		40 504	
185	#179 OR #180 OR #181 OR #182 Or #183 Or #184		351 706	
186	Postoperative Complications		305 395	
187	Respiratory Complications		91 780	
188	Respiratory Tract Diseases		59 692	
189	Respiration Disorders		20 968	
190	Pulmonary Atelectasis		5 239	
191	Pneumonia		156 083	
192	Postoperative Pulmonary Complications		22 959	
193	#187 OR #188 OR #189 OR #190 OR #191 Or #192		317 102	
194	#186 AND #193		33 707	
195	#185 AND #194		8 816	
196	Risk		3,123,366	
197	Risk assessment		485 733	
198	Preoperative Period		42 944	
199	Preoperative Care		50 163	
200	Preoperative Screening		6 444	
201	Prediction		807 076	
202	#196 OR #197 OR #198 OR #199 OR #200 OR #201		3,914,357	
203	# 195 AND #202	*SEARCH A*	4 173	**60**
204	Risk Factors		1,482,977	
205	Patient Characteristics		515 050	

206	#204 or #205		1,925,654	
207	#195 AND #206	*SEARCH B*	2 012	**50**
208	Length of Stay		105 597	
209	Intensive Care Unit OR Intensive Care		201 258	
210	ICU Stay OR Intensive Care		204 999	
211	#208 OR #209 OR # 210		288 686	
212	#195 AND #211	*SEARCH C*	1 366	**77**

2.3.2 Eligibility & Inclusion

The table below summarises the papers included in the review together with their assigned 'CASP' score.

Table 7: Screening for eligibility using the CASP Score

Authors	Title	CASP Score
Topal, A. & Eren, M. (2012)	Risk factors for the development of pneumonia post cardiac surgery	7/10
Spivack, S. et al. (1996)	Preoperative Prediction of Postoperative Respiratory Outcome	8/10
Hulzebos, E. et al (2003)	Prediction of Postoperative Pulmonary Complications on the Basis of Preoperative Risk Factors in Patients Who Had Undergone Coronary Artery Bypass Graft Surgery	7/10
Filsoufi, M. et al (2008)	Predictors and Early and Late Outcomes of Respiratory Failure in Contemporary Cardiac Surgery	10/10
Canver, C. & Chanda, J. (2003)	Intraoperative and postoperative risk factors for respiratory failure after coronary bypass	9/10
Rahmanian P. et al (2010)	Predicting Hospital Mortality and Analysis of Long-Term Survival After Major Noncardiac Complications in Cardiac Surgery Patients	10/10
Naughton, C. et al (2003)	Factors determining the duration of tracheal intubation in cardiac surgery: a single-centre sequential patient audit	10/10
Kollef, M. et al (1995)	Determinants of Mortality and Multiorgan Dysfunction in Cardiac Surgery Patients Requiring Prolonged Mechanical Ventilation	8/10
Yazdanian, F. et al (2013)	Cardiac Variables as Main Predictors of Endotracheal Reintubation Rate after Cardiac Surgery	8/10
Michalopoulos, A. et al (2006)	Frequency, characteristics and predictors of microbiologically documented nosocomial infections after cardiac surgery	8/10
Sawatzky, J. & Naimark, B. (2009)	The coronary artery bypass graft surgery trajectory: Gender differences revisited	9/10
Faritous, Z. et al (2011)	Perioperative risk factors for prolonged	7/10

	mechanical ventilation and tracheostomy in women undergoing coronary artery bypass graft with cardiopulmonary bypass	
Ried, M. et al (2011)	Female Gender and the Risk for Death After Cardiac Surgery in Septuagenarians and Octogenarians: A Retrospective Observational Study	8/10
Paone, G. et al (1998)	Does Age Limit the Effectiveness of Clinical Pathways After Coronary Artery Bypass Graft Surgery?	7/10
Rodriguez, R. et al (2002)	Cardiac Surgery in Elderly Patients	8/10
Faggian, G. et al (2011)	Urgent cardiac surgery in octogenarians	9/10
Yin, Y. et al (2007)	Risk Factors Affecting Adverse Outcomes of Cardiac Surgery in Patients Aged 70 Years and Older	8/10
Al-Alao, B. et al (2012)	Propensity analysis of outcome in coronary artery bypass graft surgery patients >75 years old	9/10
Lola, I. et al (2011)	Are there independent predisposing factors for postoperative infections following open heart surgery?	9/10
Wigfield, C. et al (2006)	Is extreme obesity a risk factor for cardiac surgery? An analysis of patients with BMI ≥40	8/10
Moulton, M. et al (1996)	Obesity Is Not a Risk Factor for Significant Adverse Outcomes After Cardiac Surgery	8/10
Ngaage, D. et al (2002)	The impact of the duration of mechanical ventilation on the respiratory outcome in smokers undergoing cardiac surgery	8/10
Al-Sarraf, N. et al (2008)	Effect of Smoking on Short-Term Outcome of Patients Undergoing Coronary Artery Bypass Surgery	8/10
Jones, R. et al (2011)	Current smoking predicts increased operative mortality and morbidity after cardiac surgery in the elderly	8/10
Cohen, A. et al (1995)	Chronic Obstructive Pulmonary Disease in Patients Undergoing Coronary Artery Bypass Grafting	10/10
Saleh, H. et al (2012)	Impact of chronic obstructive pulmonary disease severity on surgical outcomes in patients undergoing non-emergent coronary artery bypass grafting	10/10
Johnson, B. et al (2001)	Pulmonary Function in Patients With Reduced Left Ventricular Function. Influence of Smoking and Cardiac Surgery	7/10
Bastos, T. et al (2011)	Influence of respiratory muscle strength in evolution of patients with heart failure after cardiac surgery	8/10

2.3.3 Inclusion

Utilising the inclusion criteria and with both reviewers in agreement, the original 127 papers yielded by the various searched undertaken, were then deducted to 28 when reviewed using the CASP critical appraisal tool. According to the CASP checklist, it was decided, the following 12 papers would not be included in the review: (Strabelli, 2008; Wahl, G. et al, 1993; Bacchetta, M. et al, 2003; Durukan, A. et al, 2013; Yazdanian, F. et al, 2007; Akdur, H. et al, 2006; Sivakumar, S. et al, 2007, Kortekaas, K. et al 2012; Santos, M. et al, 2011; Mistiaen, W & Vissers, D, 2008; Chan et al, 2012; Morricone et al,1999).

The PRISMA flow diagram below provides a summary of the information necessary to follow the different phases of this systematic review (Figure 4). It displays the number of papers identified and those included and excluded from the review. (PRISMA, 2009) Papers were excluded from the review if they did not fulfill the inclusion criteria (2.2.4) or if they failed to reach the level of quality scoring being 7 out of 10 for inclusion.

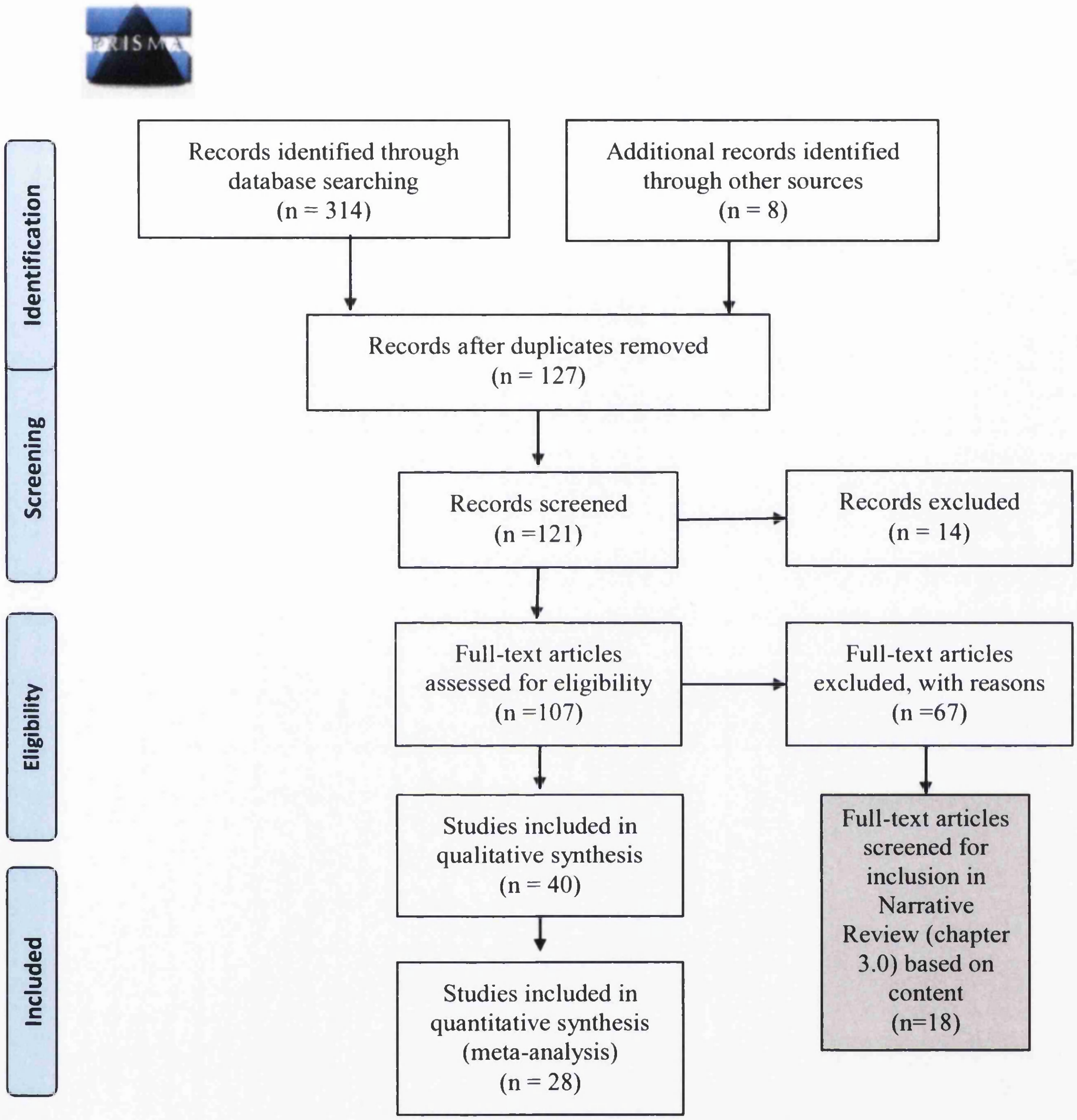

Figure 4: PRISMA (2009) Flow Diagram

The table below is a summary of the articles included in this review.

Table 8: Summary table for articles included

Author	Patient Group	Design	Outcome	Key Results
Topal & Eren (2012)	162 pts who underwent all cardiac surgery up to Nov 2009	Retrospective	Nosocomial Pneumonia	Incidence of Pneumonia was 13%. Regression analysis revealed the number of transfused units of blood, previous COPD and postop AF as independent predictors of pneumonia.
Canver & Chanda (2003)	8,802 consecutive pts who underwent primary CABG with or without a concomitant procedure from Jan, 1993 to Dec 2000	Retrospective	Respiratory Failure	5.6% of pts suffered respiratory failure. CPB time, sepsis, endocarditis, gastrointestinal bleeding, renal failure, deep sternal wound infection, new stroke or bleeding were events that significantly contributed to respiratory failure following CABG surgery.
Filsoufi et al (2008)	6,326 consecutive patients undergoing cardiac surgery from Jan, 1998 to Dec, 2005	Retrospective Cohort study	Respiratory Failure	Incidence of respiratory failure was 9.1%. renal failure, aortic procedures, haemodynamic instability and IABP were predictors of respiratory failure.
Hulzebos et al (2003)	117 pts who underwent elective CABG surgery between Dec, 1998 and Feb, 1999	Prospective Cohort study	High and Low risk for PPC's	Results showed that factors associated with the development of PPC's were age>70, productive cough, diabetes mellitus and smoking.
Spivack et al (1996)	513 consecutive pts undergoing cardiac surgery between April 1991, and March, 1992	Observational Study	PMV	Incidence of PMV was 8.3%. LVEF with the presence of pre-existing comorbid conditions including smoking, CCF, angina and diabetes were moderate risk factors for PMV.
Naughton et al (2003)	311 consecutive pts who underwent cardiac surgery over a 15 week period	Prospective	Early Tracheal Extubation	Early extubation was not associated with reduced LOS. The results indicated a relationship between delayed extubation and poor LV function, renal and pulmonary function.

Yazdanian et al (2013)	1,000 pts undergoing all cardiac surgery over a 5-month period ending March, 2009.	Prospective Observational study	Reintubation	The incidence of reintubation was 2.6%. Predictors of reintubation were lower preoperative and postoperative EF, valvular disease, arrhythmias, IABP.
Kollef et al (1995)	472 consecutive pts admitted for cardiac surgery between Aug, 1993 and March, 1994	Prospective cohort study	Mortality and Multi-organ Dysfunction PMV	The results found the development of an OSFI >3 was the only characteristic associated with IU mortality. Incidence of PMV was 22.7%.
Rahmanian et al (2010)	7,714 consecutive cardiac surgical pts from Jan, 1998 to Dec, 2006	Retrospective Observational study	Incidence of early and mid-term mortality after major complications	The most common complication was respiratory (9.5%). In hospital mortality was 3.9% and for those patients who developed a single complication, this increased to 12.0%. 10 preoperative factors were found to be predictors of operative mortality.
Michalopoulos et al (2006)	All patients undergoing open heart surgery from June, 1996 to Sept, 1997 (n=314)	Prospective case controlled study	Postoperative Nosocomial Infection	Incidence of nosocomial infection was 5.0%. The most common was respiratory infection (45.7%). Factors found to be predictors for nosocomial infection were history of immunosuppression, transfusion of >5 units and acute renal failure.
Lola et al (2011)	172 pts who underwent CABG surgery from May, 2006 to March, 2008	Prospective	Early Postoperative Infection	Infection occurred in 13.95% of patients. The most common infection was superficial wound infection, CVC infection and pneumonia.
Sawatzky & Naimark (2009)	257 consecutive pts scheduled for elective or urgent CABG at 2 tertiary care centres	Prospective Cohort Study	Postoperative Morbidity and QOL	The results demonstrated a male advantage as women were found to have significantly more PPC's (p=0.005), a longer hospital stay (p=0.003).
Ried et al (2011)	598 pts aged between 70 and <90 years who underwent cardiac surgery between Jan, 2006 and Aug, 2009	Retrospective Observational Study	In-Hospital Mortality and Postoperative Morbidity	Mean logistic EuroSCORE differed significantly between gender groups, 11.9% in women, 9.9% in men (p=0.007). Otherwise in-hospital mortality did not differ between groups.
Faritous et al (2011)	5,497 female pts undergoing CABG surgery from April	Retrospective	Incidence of PMV PPC's	31 pts required PMV and of these 15 pts required a tracheostomy. 7 factors were

	2002 to March, 2008.			determined as independent predictors of PMV. Female gender was found to be associated with poorer outcome including the risk of PPC's and prolonged LOS.
Rodriguez et al (2002)	Longitudinal in design over a 17 year period from 1985 to 2001. 1305 patients included were aged from 65 to 90 years.	Retrospective Observational Study	Postoperative complications	Mean hospital mortality was 16%. Comorbidities were found to increase with age ($p<0.05$). Independent risk factors were creatinine levels >2mg/dl, combined surgery and previous surgery.
Al-Alao et al (201)	2804 consecutive pts having first time isolated CABG surgery during Jan, 2000 to Dec, 2008.	Retrospective Cohort study	In-Hospital Mortality Morbidity Length of hospital stay Postoperative complications	11.1% of patients were >75 years. Observed complications of pulmonary, cardiac, renal, gastrointestinal, neurological, infective and mortality rates were significantly higher in the elderly group ($p<0.0001$). Elderly patients were found to have longer duration of ventilation, LOS and mortality rate ($p<0.05$).
Faggian et al (2011)	667 pts aged 80 years or older who underwent cardiac surgery from Jan, 1998 to, Dec, 2007	Prospective	Postoperative complications LOS in ICU In-Hospital Mortality	Overall mortality was 12.0%. The most common cause of death were infections i.e. Pneumonia (23%) renal (20%). For octogenarians, a mortality rate of 8% was considered acceptable.
Yin et al (2007)	952 pts over a 3 year period from Aug, 2004 to Dec, 2006.	Retrospective	In-Hospital Mortality Major Postoperative Morbidity Prolonged LOS in ICU	Mortality was higher for the elderly group, as was the LOS ($p<0.05$).
Paone et al (1998)	445 consecutive pts that underwent isolated CABG surgery between Jan, 1996 to Jan, 1997.	Retrospective	In-Hospital Mortality LOS Postoperative Complications	Mortality and LOS were higher for the elderly group and there were higher incidences of blood transfusion, AF and overall rate of complications.
Cohen et al (1995)	651 pts having CABG surgery during June, 1991 to June, 1993.	Prospective	LOS in ICU Total LOS Morbidity In-Hospital Mortality	The results of patients with severe COPD were not favourable, a prolonged ICU stay ($p=0.001$) and a longer hospital stay ($p=0.0236$).

Saleh et al (2012)	11,217 consecutive pts undergoing non-emergent CABG between April, 1997 and Sept, 2010	Retrospective	Early Mortality Postoperative complications PMV	The results confirmed COPD as a significant risk factor for mortality and morbidity and the development of postoperative complications ($p<0.001$).
Al-Sarraf et al (2008)	2587 consecutive pts having isolated CABG surgery from 2000 to 2007	Retrospective	In-Hospital Mortality Postoperative Morbidity LOS in ICU	Current smokers had higher rates of PPC's ($p<0.001$). Rates of other complications, LOS and mortality were not found.
Ngaage et al (2002)	2163 pts undergoing elective cardiac surgery between 1993 and 1999	Retrospective Cohort study	Duration of Mechanical Ventilation LOS in ICU Incidence of PPC's	Active smokers have a comparatively poorer postoperative respiratory outcome and are at greater risk for the development of PPC's beyond 6 hours of ventilation ($P<0.002$).
Jones et al (2011)	All cardiac surgical pts undergoing surgery over a 5-year period ending March, 2007 (n=1,108)	Retrospective Observational study	Preoperative co-morbidity Intraoperative factors Mortality and Morbidity	Patients >70 years and current smokers had significantly higher rates of PPC's ($p<0.002$). Active smokers had a longer ICU stay ($p=0.002$) more ICU readmissions ($p<0.0002$) and a higher in-patient mortality ($p<0.0001$).
Moulton et al (1996)	2,299 pts who underwent cardiac surgery during Jan, 1991 to Dec, 1993	Prospective	Operative Mortality Arrhythmias ARDS PE Renal failure Wound infection Sepsis LOS ICU	Of this cohort 25% of patients were obese (BMI >30) and was found to be a risk factor only for sternal wound infection ($p<0.01$), leg infections ($p=0.05$) and atrial dysrhythmias ($p=0.04$). Obesity was not found to be a risk factor for adverse outcome following cardiac surgery.
Wigfield et al (2006)	1920 consecutive cardiac surgical pts from Jan, 1999 to May, 2004	Retrospective	Operative Mortality LOS of ICU Postoperative Complications	Patients with extreme obesity (BMI >40) developed significantly more postoperative complications and prolonged LOS ($p<0.01$)
Johnson et al (2001)	324 pts were recruited from a heart failure clinic from 1994 to 1998	Retrospective	PFT's	Smokers with CHF had reduced expiratory flow ($p<0.05$). There is a weak correlation between LV function and lung volumes.
Bastos et al (2011)	40 pts with compensated systolic/diastolic heart failure admitted for elective cardiac surgery	Prospective Cohort study	LOS in ICU Incidence of PPC's	Preoperative muscle dysfunction in patients with heart failure did not influence the incidence of PPC's.

2.4 Discussion

This systematic review aimed to examine the research evidence relating to risk factors and patient characteristics as predisposing factors for PPC's. The studies have demonstrated that over the past twenty years there have been several endeavors aimed at the prediction of postoperative pulmonary complications for predicting adverse respiratory outcomes following cardiac surgery.

2.4.1 Risk Factors as Determinants for the Development of PPC's

A recent study by Topal and Eren in 2012, aimed to identify the potential risk factors for the development of nosocomial pneumonia following cardiac surgery. Also, by the identification of preventable risk factors aiming to contribute to the reduction of this complication. They performed a retrospective analysis on the last 162 patients who underwent all cardiac surgery a single centre up to November, 2009. They excluded patients who were on immunosuppressive therapy and those with any identifiable infection preoperatively. Patients were grouped into those with pneumonia (n=21) and those without (n=141), and the definition of pneumonia was based upon clear objective markers, therefore is easily replicated. Data was collected on possible risk factors associated with pneumonia including preoperative variables, operative and postoperative variables. However, there was no evidence of blinding. The authors took into account of a detailed list of confounding variables which was the supported with robust statistical analysis using a multivariate logistic regression model.

Postoperative pneumonia was diagnosed in 21 patients (13%) and the results showed that the remaining time in ICU and the mean LOS in hospital was higher for those patients with postoperative pneumonia. The regression analysis highlighted that the number of units of transfused packed red blood cells (RBC), previous COPD and postoperative atrial fibrillation (AF) as independent predictors for the development of pneumonia.

Although the results of this study are plausible, the findings are based on upon a small sample, as only 21 patient had pneumonia. However, an important consideration influencing the robustness of the results were the differences between the participants across the two groups as the percentage of patients with previous COPD and diabetes were greater in the group with pneumonia, although this was recognised by the authors. The CASP assessment of this paper was 7 out of 10.

In an earlier study, Canver and Chanda (2003) aimed to identify intraoperative and postoperative risk factors that would predispose patients to pulmonary impairment after CABG surgery. Data was collated from a single institution perfusion database and from the mandatory report submitted to the cardiac surgery registry. A total of 8,802 consecutive patients (6,234 males; 2,568 females) who underwent primary CABG with or without a concomitant cardiac procedure from January, 1993 to December, 2000 were included in the study. The main outcome measure was respiratory failure, defined as "pulmonary insufficiency requiring intubation and ventilation for a period of 72 hours or more at any time during the postoperative stay". The authors identified all of the important confounding factors and analysed the outcomes using the appropriate univariate analysis followed by multivariate logistic regression analysis. Regarding any follow up of the subjects, although there was an element of follow up being 30 days, it was decided this was not long enough.

Of the 8,802 consecutive patients that received CABG surgery, 491 patients (5.6%) suffered postoperative respiratory failure. Initially, the univariate analysis identified 39 statistically significant risk factors for respiratory failure, yet only 6 proved statistically significant in the multivariate analysis ($p<0.001$). CPB time was the isolated intraoperative event identified and postoperatively, sepsis and endocarditis, gastrointestinal bleeding, renal failure, deep sternal wound infection, new stroke or bleeding that required reoperation were events that contributed significantly to CABG respiratory failure following surgery. Although it was felt that the findings of this study are mainly applicable to those patients undergoing CABG surgery, despite concomitant surgery being examined. Nevertheless, the CASP assessment of this study was 9.

Similarly to Canver and Chanda (2003), Filsoufi et al (2008) more recently studied the outcome of respiratory failure. The authors justified the important need to study the epidemiology of respiratory failure in a contemporary cohort of cardiac surgical patients. They set out to analyse the incidence and predictors of respiratory failure together with early and late outcomes following respiratory failure. They conducted a retrospective analysis of 6,326 consecutive patients undergoing cardiac surgery between January, 1998 and December, 2005. The main outcome parameter was respiratory failure, defined according to the New York State Department of Health as "Pulmonary insufficiency requiring reintubation and ventilation for $\geq$ 72 hours postoperatively". This criteria was used for a similar objective in the work carried out by Canver and Chanda (2003). The logistic EuroSCORE to calculate individual risk stratification was also used, which has been proven as a validated and reliable outcome measure previously.

Subjects were divided into 2 groups; those with respiratory failure (n=529) and those without (n=5,269) and the same method was applied to both groups. Patients were then classified into four risk groups: low (<3%), moderate (3 to 9%), high (9 to 25%) and very high risk (>25%). Although there was no true follow up for the patients, survival rates were examined at 1, 3 and 5 years, however, some confusions exists surrounding the data for this. In this study, the incidence of respiratory failure was 9.1% (n=529), which was greater than 5.6% reported by Canver and Chanda (2003). The highest incidence of respiratory failure was observed following combined CABG and valve surgery (14.8%) and aortic procedures (13.5%). Using a stepwise logistic regression analysis, preoperative and operative factors as predictors of respiratory failure were renal failure, aortic procedures, haemodynamic instability and the use of an IABP, which differ to the findings from Canver and Chanda (2003). The mortality rate of patients in the group with respiratory failure was 15.5% compared to 2.4% in the non-respiratory failure group ($p<0.001$), despite the EuroSCORE evaluation. The authors postulated that for those patients even with a low risk EuroSCORE will have a x15 greater risk of mortality following the onset of respiratory failure.

This study differs in that it does not solely investigate outcomes relating to CABG surgery, nevertheless it includes valve procedures and aortic surgery. This makes the findings more applicable to the local population, and thus the paper was awarded 10 for the CASP assessment.

More pertinently, Hulzebos et al (2003) addressed the risk of PPC's, which they proposed were not equal for all patients. Therefore they aimed to develop a risk model that would be based upon preoperative risk factors, in order to classify patients undergoing CABG surgery into high and low risk for the development of PPC's. Data was collected for patients undergoing elective CABG surgery between December, 1998 and February, 1999. Patients with a history of CVA, use of immunosuppressive treatment, presence of neuromuscular disorders, history of pulmonary surgery and cardiovascular instability or aneurysms were excluded from the study. Clear operational definitions of PPC's according to the definitions of the Centre's for Disease Control and Prevention was provided, as well as the definitions of various risk factors that have been previously defined by the Society of Thoracic Surgeons, and hence they are easily repeatable. Preoperative risk factors evaluated were age, gender, BMI, PFT's, diabetes, productive cough, history of cigarette smoking and scoring on the Specific Activity Scale (SAS) which is a validated scale to assess preoperative cardiac functional class. A microbiologist who was blinded for preoperative risk factors, PFT's and respiratory force test results, scored the nosocomial infections according to the definitions provided. This blinding of the outcome measure is a single-blinding procedure, which reduces the sources of bias that may affect the interpretation of the findings. In this study, despite there being separate multiple logistic regression models to determine the effects of the preoperative factors and their association with PPC's. It was felt that the authors failed to clarify what they were, which lacked detail in their analyses. Additionally, questions were raised regarding the suitability of the Kolmogorov-Smirnov as a "goodness of fit" test, as it is more suitably appropriate as a test for normality of data.

The results revealed that preoperative risk factors associated with the development of PPC's were age >70 years, productive cough, diabetes mellitus and a history of cigarette smoking. Additionally, within the spirometric data, protective factors for the development of PPC's were a predicted inspiratory vital capacity of ≥75% and a predicted maximal expiratory pressure of ≥ 75%, with a sensitivity of 87% and a specificity of 56%, suggesting the value of PFT's preoperatively. However, as found previously, these findings can be applied locally, but are only applicable to the cohort undergoing CABG surgery, which is a limitation of this study.

It appears as though the literature surrounding the development of PPC's are often in relation to the putative risk factors discussed. This is only one aspect of the challenge, it is also rather pertinent to view these risk factors and characteristics and their influence on adverse postoperative respiratory outcomes as a whole, including, PMV, early extubation and reintubation as adverse clinical outcomes. This is essential in understanding PPC's from a broader perspective.

2.4.2 Risk Factors as Determinants of Adverse Clinical Outcome

Spivack et al (1996) recognised that there was a need to create a preoperative test that "would reliably identify those patients destined for a complicated postoperative respiratory course". They tested a hypothesis of traditionally defined preoperative risk factors that predict PMV after CABG surgery, and aimed to quantify the power of these factors. An observational study of 513 consecutive patients undergoing CABG between April, 1991 and March, 1992 were evaluated and then subdivided according to the urgency of their surgery into emergent, urgent or elective. In examining the predictive values of a set of commonly used preoperative clinical and pulmonary function parameters by combining them to yield a postoperative regression model for the group. For example, gender, age, smoking history, clinical congestive cardiac failure, unstable angina, previous CABG, recent MI, diabetes, PFT's and cardiac function as assessed by left ventricular ejection fraction (LVEF). Furthermore, they conducted a second sub-group analysis using classification and regression tree analysis. The outcomes assessed were objective, namely duration of mechanical ventilation (hours), duration of surgical ICU stay (days) and mortality (%), however no timeframe was given for the follow-up.

All consecutive patients were included giving each subject an equal chance of inclusion and the same measurement methods were applied to all 3 groups.

The multivariate regression analyses revealed that for an elective patient undergoing CABG, the risk of PMV and death were rare, 8.3% and 2.0% respectively. The results also showed that reduced LVEF together with the presence of pre-existing co-morbid conditions including current smoking, clinical congestive cardiac failure, angina and diabetes were found to be modest risk factors for PMV. Age or COPD were not found to be risk factors in surgical outcome overall. No pulmonary diagnosis, mechanical PFT's or blood gas parameter substantially contributed to predicting adverse outcome. This suggests that they do not offer a prediction for poor postoperative respiratory outcome which is in contrast to the suggestion from Hulzebos et al (2003) who advocate the use of PFT's.

Of a similar nature to the work carried out by Spivack et al (1996), Naughton et al (2003) designed a prospective study to identify those factors associated with early tracheal extubation following cardiac surgery. Data was prospectively collected on 311 consecutive, unselected patients undergoing cardiac surgery over a 15-week period. A clearly defined standardised protocol was provided for extubation, and was used to create groups to compare based upon prospective categorization: extubated within 6 hours; >6 and 24 hours; >24 and 48 hours and >48 hours, and the main outcome used was the time to tracheal extubation. The same procedure was consistent across the 4 groups. Univariate analysis was performed on each variable including preoperative, perioperative and postoperative characteristics of each of the groups. Variables that were significant in the univariate analysis were selected for inclusion in the multivariate analysis model. Subjects were then followed up for 15 weeks, although the rationale behind this was not justified.

The results of this study indicated that delayed extubation >6 hours post-surgery was not related to age, gender, BMI, previous angina or MI, diabetes and postoperative AF. However, it did indicate a relationship to exist was associated with poor left ventricular function (ejection fraction <30%), renal and pulmonary function as well as a high EuroSCORE. Early extubation i.e.<6 hours, was not associated with reduced LOS, moreover, the authors discussed potential organizational factors delaying discharge from the intensive care at the time of study. Overall, it was concluded that those patients who were extubated beyond 24 hours had a longer LOS in hospital and a greater incidence of postoperative complications, including arrhythmias, respiratory, gastrointestinal, renal and neurological complications.

The study attained a CASP score of 10, and reinforced the findings from Spivack et al (1996), Filsoufi et al (2008) and Canver and Chanda (2003), in relation to predictive factors.

In a recent publication, Yazdanian et al (2013) set out to determine the reintubation rate factors that related to postoperative cardiac surgery and outcome of those adult patients undergoing cardiac surgery. A prospective observational study was used, over a 5-month period ending March, 2009 that included all adult patients undergoing all types of cardiac surgery using CPB. Patients excluded were those already intubated prior to surgery and those who underwent Cardio-Pulmonary Resuscitation or cardiogenic shock or emergency surgery. The objective measurements used were preoperative characteristics including age, gender, NYHA, LVEF and smoking and postoperative characteristics including complications and in-hospital mortality. Additionally, more specific objective measurements were used a variables such as Pa02, PaC02 and inotropic therapy. For these measurements, although the criteria used were clear and valid, confusion exists as to whether or not they were used as a deciding factor for reintubation? Patients were then divided into 2 groups; those reintubated (2.6%) and non-reintubated patients. Furthermore, the authors failed to provide a defined protocol for reintubation, which questions the process and the system for ensuring reliability, which influenced the scoring of this paper.

2.6% of the 1000 patients studied required reintubation and it was mainly due to respiratory, cardiac or neurological reasons. Univariate analysis indicated that advancing age and cardiac variables as predictors of reintubation. However, the multivariate analysis revealed that a lower preoperative and postoperative EF, valvular disease, arrhythmias and postoperative IABP as independent predictors of reintubation. Overall it was argued that cardiac variables were more common and significant predictors of reintubation after cardiac surgery in comparison to respiratory. Despite the lack of detail surrounding the protocol for reintubation, the overall findings can be applied to the local population and the study achieved a CASP score of 8. This work by Yazdanian et al (2013) corroborates the findings of Naughton et al (2003).

Other papers have examined risk factors as determinants of mortality and multi-organ dysfunction in cardiac surgery patients.

In 1995, Kollef et al conducted a prospective cohort study that sought to identify the characteristics associated with mortality and the development of multi-organ dysfunction in patients who had undergone cardiac surgery and required PMV for greater than 48 hours. The study included 472 consecutive patients admitted for cardiac surgery between August, 1993 and March, 1994, and all patients who were intubated and ventilated for longer than 48 hours were evaluated. Those patients intubated for less than 48 hours were excluded to select the population cohort. The primary outcomes were ICU mortality, duration of mechanical ventilation, length of ICU stay and multi-organ dysfunction, as classified by OSFI (Organ System Failure Index). All definitions and classifications used were clearly defined and validated. Although a multivariate analysis was performed, a true regression analysis of the variables was not. Of the 472 consecutive patients, 22.7% (n=107) required PMV. The results found the development of an OSFI of greater than 3 was the only characteristic independently associated with ICU mortality ($p<0.001$). Factors found to be independently associated with the development of an OSFI of 3 or greater, were the presence of an antibiotic resistant infection, an aortic cross-clamp time of >1.25 hours, VAP and APACHE (Acute Physiology and Chronic Health Evaluation) of ≤ 30. For patients requiring PMV, acquired multi-organ dysfunction was found to be the best predictor for mortality in this study. The choice in statistical analysis and the lack of detail surrounding the follow-up of the patients reduced the CASP score to 8.

Of a similar nature to Kollef et al (1995), although more recently, Rahmanian et al (2010) conducted a retrospective analysis of 7,174 consecutive cardiac surgical patients from January, 1998 to December, 2006. The authors investigated the incidence of early and mid-tern mortality after major complications develop following cardiac surgery. Of the main sample cohort of 7,714 patients, which is on a larger scale than the sample used by Kollef et al (1995), patients were divided into 2 groups, those with complications (n=826) and those without (n=5,815). The main outcomes were based upon six major complications, for which the authors provide evidence based definitions: 1) respiratory failure 2) sepsis 3) dialysis dependent renal failure 4) deep sternal wound infection 5) gastro-intestinal complications and 6) stroke. In addition, in-hospital mortality was defined as death within the same admission or within 30-days of surgery. This timeframe appears to be a standardised definition of in-hospital mortality within the literature (Canver and Chanda, 2003; Rahmanian et al, 2010; Yazdanian et al, 2013). Other outcomes investigated include LOS in hospital. All confounding factors were taken into account, and was followed by a stepwise multivariate logistical regression analysis. It could be argued, the follow up of the patients up to mid-term survival at one year was insufficient.

A total of 1,354 complications were observed in this study, and the most common was respiratory (n=634; 9.5%) which supports the findings of Yazdanian et al (2013) and is consistent with the incidence of respiratory failure at 9.1% reported by Filsoufi et al (2008). The in-hospital mortality overall was 3.9%, and for those patients who developed a single index complication, mortality increased to 12.0% (n=58). Ten preoperative factors including female sex, age>70 years, ejection fraction <30%, peripheral vascular disease, creatinine levels of >2.5, acute MI, haemodynamic instability, emergent procedure, reoperation, procedures other than CABG, and postoperative respiratory failure, sepsis, stroke, renal failure and gastro-intestinal complications were found to be predictors of operative mortality. Those patients found to have 3 or more complications and a LOS of > 60 days, one-year survival was evident in less than 50% of patients. This paper achieved a score of 10.

Moreover, when considering adverse outcomes, other studies have focused on recognising postoperative nosocomial infections to represent serious problems following cardiac surgery. Michalopolous et al (2006) aimed to identify the frequency, characteristics and risk factors as determinants for postoperative infection in a cohort. In this prospective case-controlled study, all adult patients undergoing open heart surgery with the use of extracorporeal circulation from June, 1996 to September, 1997 (n=314) were included. In this study, cases were patients who develop microbiologically documented nosocomial infection (n=107). Controls were those who underwent cardiac surgery during the two consecutive months of the study period but did not develop a nosocomial infection (n=314). However, it was not stated if the control group was case-matched for age and gender. The authors provided detailed clinical features to define the variety of nosocomial infections i.e. pneumonia, endocarditis, urinary tract and wound infection which reflects reliability amongst the measurements. For both groups, data was collected relating to patient factors, surgery related factors and postoperative complications. Although for the objective measurements used, no blinding procedures were apparent and thus an element of bias cannot be excluded. Furthermore, the follow-up of the patients appeared to be comprehensive however, it was argued that a "follow-up" for the first two postoperative days was too short.

The results of this paper demonstrated 107 of 2122 (5.0%) of patients developed a microbiologically documented nosocomial infection with an in-hospital mortality rate of 16.8%. The majority of infections were respiratory tract (45.7%) and central venous catheter (CVC) related infections (25.2%). In a multivariable logistic regression model, a history of immunosuppression, transfusion of more than five RBC units in both the operating room and during the first ICU postoperative day and acute renal failure within the first two postoperative days were found to be independent predictors of nosocomial infections after cardiac surgery.

These findings of respiratory nosocomial infections to be the most common are consistent with the findings reported by Rahmanian et al (2010).

In a latter study, Lola et al (2011) also examined the incidence of early postoperative infections in patients undergoing CABG surgery in order to analyse the type of infection and responsible pathogens and also the contributing risk factors. Utilising a prospective study design, 172 patients who underwent open heart surgery during May, 2006 to March, 2008 were enrolled and a clear detailed exclusion criteria was made available. As previously noted in the work carried out by Michalopolous et al (2006), the diagnosis of infection was microbiologically confirmed, although there was no evidence of blinding. The definition of nosocomial infections were based upon those proposed by the Centre's for Disease Control and Prevention. Patients were divided into two groups: those with infection (n=24) and those without (n=148). Preoperative, intraoperative and postoperative variables were collected and examined. The duration of the follow-up of the patients was unclear. Infection occurred in 13.95% of patients (n=24) and the most common was superficial wound infection followed by CVC infection and pneumonia. For those patients with infection, the mortality rate of 25% was higher than 5.4% for patients without infection, and this is higher than found previously by the study of Michalopolous et al (2006). Diabetes mellitus, the duration of mechanical ventilation, the development of severe complications in the ICU and readmission were independent risk factors associated with nosocomial infections after cardiac surgery, which differs to the factors identified by Michalopolous et al (2006). Although the findings can be applied to the local population, they are based upon a small cohort of patients. Despite this, the paper achieved a CASP score of 9.

The literature surrounding the risk factors for development of PPC's and thus linked to adverse clinical outcomes, reinforces the complex nature of the cardiac surgical patient profile. However, of the risk factors identified there is a consensus among the studies in this review that have specifically identified gender, age, smoking history, COPD, obesity and LVEF as predictors for complications following cardiac surgery, which will now be examined and summarised individually.

2.4.3 Risk Factor: Gender

When considering future strategies for optimising cardiac surgery outcome, Sawatzky and Naimark (2009) investigated if there were significant gender differences in both physiological and psychological dimensions of the preoperative status and postoperative morbidity and quality of life (QOL). It was argued that women tend to present for surgery with a "less favourable risk profile" (Sawatzky and Naimark, 2009). This was a prospective cohort study that included consecutive patients that were scheduled for elective or urgent CABG at 2 tertiary care institutions. Purposive sampling recruited 257 patients and these were followed from the time placed on the waiting list, through surgery to hospital discharge, then at intervals of 2 weeks, 6 weeks and 6 months postoperatively.

Data was collected on preoperative factors including demographic, socioeconomic and social support variables, co-morbidities and severity of CHD via a CABG surgery risk assessment. Additionally surgical outcomes were operationally defined within the dimensions of the QOL measures including the Short-Form 36 (SF-36). This is a general indicator of health status, and the Duke Activity Status Index (DASI) which is a scale of functional capacity. Both of these measures are validated and reliable outcome measures, together with morbidity. Patients were included if patients could read, write and speak English, they could be contacted by telephone and had their surgery on an elective or urgent basis. This system for inclusion generates uncertainty surrounding all the subjects having an equal chance for inclusion in the study. This could have introduced a source of bias in their selection criteria. Although, for all subjects included, the same subjective and objective measurements were applied, however there was no evidence of blinding. Although a variety of important confounding factors were identified by the authors, CPB time was not accounted for.

The results demonstrated a male advantage across the CABG trajectory and women were found to have increased PPC's ($p=0.005$), a longer hospital stay ($p=0.003$), to have more symptoms at 2 weeks postoperatively, a lower QOL at 6 weeks and at 6 months post-discharge. The authors have confirmed that female sex is associated with poorer outcome following cardiac surgery and put forward the need for creative strategies to improve the preoperative risk profile especially for women, to achieve optimal outcomes (Sawatzky and Naimark, 2009). As found previously, the findings of this study can be applied to the local population undergoing CABG surgery. This paper was awarded a CASP score of 9.

Similarly to the previous study, and more recently within the work of Ried et al (2011) assessing a clear hypothesis, that among specifically septuagenarians and octogenarians, women have poorer outcomes compared with men after cardiac surgery. Based in Germany, a retrospective, observational study was performed, that enrolled patients aged between 70 and <90 years who underwent cardiac surgery between January, 2006 and August, 2009. A cohort of 598 patients were reviewed that included 274 female and 324 male subjects who were matched for age and operative procedures, however there was no randomisation. Preoperative variables examined were as defined in the EuroSCORE. The primary end-points were the proportion of men and women with an in-hospital 30-day mortality and postoperative morbidity was considered as a secondary end-point. All of the data was validated by 2 investigators in an attempt to reduce errors.

Although it was accepted by the authors, there may have been a bias in the selection of women for surgery. Additionally, it was noted that although data was collected for both female and male patients, only females were discussed. This suggests an implicit bias in their patient selection. The patients were followed-up for only 30 days which was felt to be too short, in comparison to other studies.

With respect to their preoperative profile, it was found that the mean logistic EuroSCORE differed significantly between gender groups, 11.9% in women and 9.9% in men (p=0.007). Otherwise in-hospital mortality and 30-day mortality were not significantly different between genders as there were no differences between mortality for both age groups. On the multivariate analysis, age and female gender were not found to be independent risk factors for early mortality. This paper attained a CASP score of 8. However, the findings are not in agreement with Sawatzky and Naimark (2009).

Faritous et al (2011) purposefully assessed the preoperative risk factors related to PPC's and PMV and the need for a tracheostomy in women undergoing CABG with CPB. A retrospective study was performed that enrolled all female patients undergoing CABG surgery from April, 2002 to March, 2008. Of the 5,497 patients, 31 patients required PMV and the remaining 5,466 did not. From this group, 350 patients were identified with "normal condition" i.e. were extubated within 6 to 8 hours from surgery, and patients were then selected randomly from this group to yield a group for the purpose of comparison. PMV in this study was defined as uninterrupted mechanical ventilation for more than 14 complete days. Although this definition was explicitly defined it lacked any justification, and appears ambiguous. This study included all female patients, therefore this is highly selective and introduces an implicit bias in their selection, a flaw as found elsewhere from the work of Ried et al (2011), which reduced the CASP score to 7.

Of the 5,497 women undergoing cardiac surgery, 31 required PMV and of these 15 required a tracheostomy. After a multivariate analysis using a binary logistic regression model, 7 factors were determined as independent predictors as perioperative risk factors for PMV. The authors concluded that age ≥70 years, LVEF ≤30%, pre-existing respiratory or renal disease, emergency or re-do surgery, and the use of preoperative inotropes as main risk factors determined in this study.

In this review, female gender has been found to be associated with poorer outcome following cardiac surgery including increased the risk for PPC's and a prolonged length of stay. Although there is evidence in relation to in-hospital mortality, however there were no differences were found between genders. Despite the studies included in this review being highly selective in their cohorts towards female gender, however the aspect of gender has emerged as a renowned risk factor to be recognised.

2.4.4 Risk Factor: Age

In recognition of the ageing population requiring cardiac surgery today, Rodriguez et al (2002) set out to evaluate the evolution of the true position of cardiac surgery in elderly patients, which in this study was classed >70 years of age. However the definition of 'elderly' is often arbitrary. This work was based upon a retrospective observational study, longitudinal in design over a 17 year period of surgical activity from 1985 to 2001. It included a wide range of patients from 65 to 90 years old, totaling 1305 patients with a mean age of 73.7 years. 654 patients underwent valve surgery, 531 patients required surgery for coronary disease and 120 patients required combined valve and CABG surgery. Then a second analysis was performed that included patients who underwent surgery in the last 3 years (1999 to 2001). With the aim of obtaining a large enough cohort to draw significant conclusions from, patients with other disorders, i.e. pericardial or aortic were excluded.

Data was collected on demographics and preoperative morbidity of the cohort i.e. COPD, renal failure, vascular disease etc. and postoperative complications including respiratory and kidney failure, infections, neurological complications and mortality. The same measurements were applied to all patient groups, although there was no evidence of blinding. The results were then analysed using an appropriate logistic regression analysis to study the factors predictive of postoperative complications.

Although the authors took into account historical data in this study (i.e. preoperative), confusion surrounds the follow-up of patients, despite there being a second retrospective analysis that included different patients. Therefore this questions the integrity of any follow-up procedures as there does not appear to be any evidence of this, which lowered the CASP score.

Over the study, the mean hospital mortality was 16% but when compared to the second dataset, this reduced to 11%, although there was increased morbidity. Co-morbidity and complications were found to increase with age ($p<0.05$). Independent risk factors for postoperative complications were creatinine levels >2mg/dl, combined surgery and prior surgery. It was also found that the presence of any complication in the postoperative period, i.e. renal, respiratory, infection or MI, were independent predictors of mortality.

The findings from Rodriguez et al (2002) can be applied locally and this paper achieved a score of 8.

Recently, Al-Alao et al (2012) examined whether complication rates and resource utilisation among elderly patients undergoing CABG surgery differed from their younger counterparts, in a propensity matched cohort. A retrospective, single centre cohort study where 2804 consecutive patients that were having first time isolated CABG were recruited at a tertiary cardiac unit in Dublin from January, 2000 to December, 2008. Patients were stratified into 2 groups: those patients over 75 years old (n=311) and those patients under 75 years, which were a younger group based upon propensity matching of 311 patients. In this study, 'elderly' was aged >75 years, which is older than used by Rodriguez et al (2002) which demonstrates the variability that exists within the definition. The outcome measures used were considered standard clinical objective measures i.e. in-hospital mortality, morbidities, hospital stay and clear definitions of postoperative complications were provided. However, there was no evidence of blinding procedures. All consecutive patients were included and stratified into 2 groups, therefore everyone had an equal chance for inclusion. The follow-up of patients that only included 30-day mortality, could be argued as insufficient.

Overall, 11.1% (n=311) of patients were identified as >75 years. The observed complications of pulmonary, cardiac, renal, gastrointestinal, neurological, infective and mortality rates were significantly higher in the elderly group ($p<0.0001$). Furthermore, elderly patients were found to have a longer duration of ventilation postoperatively and a longer postoperative stay and a higher surgical mortality rate, 6.1% vs. 2.6%, $p<0.05$. The authors concluded that elderly patients have significantly higher rates of postoperative complications and prolonged stay and thus demand more resource utilisation. This corroborates the findings from Rodriguez et al (2002) that co-morbidities and complications increase with age.

With respect to investigating age as a risk factor, it is contended that little research is currently available on elderly patients undergoing non-elective surgery. Faggian et al

(2011) reviewed the treatment of patients older than 80 years that were operated under an urgent or emergency basis for cardiac surgery. From January, 1998 to December, 2007, 667 patients age 80 or older underwent cardiac surgery, of these 37% (n=251) required urgent or emergency surgery, which were included in the study. Preoperative variables were analysed, postoperative complications and outcomes i.e. frequency of complications, LOS in ICU, in-hospital mortality and early and long-term survival were the outcome measures used. Multivariate analysis and logistic regression were performed to identify the incremental risk factors for postoperative death. The patients follow-up was complete, and once discharged, patients were evaluated in an outpatient clinic for up to 6-monthly intervals. However, there is ambiguity surrounding the completion of the follow-up, as those individuals at follow-up and those patients assessed at the outpatient clinic appeared different, which introduced an element of potential bias.

In this study of non-elective octogenarians undergoing cardiac surgery, the results found the overall mortality was 12%, 8% in urgent cases and 45% in emergent cases. The most frequent causes of death were infections i.e. pneumonia (23%), renal failure (20%) CVA (17%), respiratory failure (10%) and multi-organ failure (10%). The incremental risk factors for early mortality were age, emergent procedures, aortic procedures, CPB time and the presence of a major complication. The authors concluded with the perspective that urgent cardiac surgery can be performed in octogenarians with acceptable operative mortality and long-term survival.

Despite there being evidence to prove co-morbidities increase with age, the results of the study by Faggian et al (2011) acknowledged this, however, the authors postulated that a mortality rate of 8% in urgent cases for octogenarians was considered acceptable. As the results of this study can be compared with other available evidence and can be applied locally, the paper was allocated a CASP score of 9 out of 10.

In understanding the risk factors specifically related to adverse outcomes of cardiac surgery in patients aged 70 years or older, Yin et al (2007) performed a retrospective study to explore this. 952 patients were included over a 3 year period from August, 2004 to December, 2006 in Taiwan. The primary outcomes studied were major adverse outcomes including in-hospital mortality, major postoperative morbidity based upon set criteria including cardiovascular, respiratory, neurological, renal, infection etc. and prolonged LOS in ICU, defined as 7 days or more. To address the study aim, patients were divided into 2 groups: a study group, which contained patients > 70 years old (n=395) and a control group which contained the rest of the patient group (n=557). Although all patients were included, there was no evidence of bias in their selection, however, the control group consisted of patients and not normal, healthy subjects, as the only difference between them was age. The authors refer to this group as a 'control group', which appears incorrect, as it should be referred to as a reference group for comparison. There was no evidence of blinding procedures and it was difficult to determine the duration of follow up, which is reflected in their CASP score.

It was found that 14.2% (n=56) died in the study group vs. 8.3% (n=46) who died in the control group. Also elderly patients in the study group spent longer on ICU, 8.7 ± 12.0 vs. 6.1 ± 10.0 days, $p<0.05$. Using a stepwise logistic regression analysis, risk factors for in-hospital mortality include renal impairment, reoperation, CHF, COPD and catastrophic state. Overall, elderly patients in this study were found to have a x1.7 fold higher mortality rate, a x1.5 fold higher morbidity rate and a greater postoperative ICU stay of more than 7 days.

The authors raised an important issue based upon the findings of this study to recognise that surgeons and anaesthetists should face the challenge to not only maximise clinical efficiency but also to have ways to manage high risk patients effectively (Yin et al , 2007).

With recognition of this, Paone et al (1998) believed that although surgery for elderly patients is gratifying, their outcomes are also associated with higher rates of morbidity and mortality and longer hospital stays. However, at their institution, the introduction of a 5-day clinical pathway, which the authors advocated to be effective in reducing LOS and costs. However, they aimed to determine whether the benefits of a clinical pathway are comparable for younger and older patients and if not, to determine which factors account for the difference. In an earlier retrospective study, 445 consecutive patients that underwent isolated CABG between January, 1996 and January, 1997 that included patients over 70 years (n=146) and <70 years (n=299). All patients in both groups were treated with the same clinical pathway and discharged on day 5 postoperatively. There was no exclusion criteria.

It has to be noted, one of the common features of the literature surrounding age in this review is the level of age which is regarded as 'elderly'. As previously stated, and highlighted in the current study 'elderly' is >70 years, which poses the question is 70 years the correct cut-off? This was not justified. However, on closer examination of the 2 groups, there are unequal numbers, with much smaller numbers of patients in the elderly group, with the younger group having almost four times as many subjects. This creates an unbalanced selection and thus has to be taken into account for the interpretation of the results of this study. Although all consecutive patients were included, there doesn't appear to be any bias in the selection process.

There is additional uncertainty regarding the statistical analysis for this study, as the appropriateness of a Chi-squared test, which would compare the association between 2 groups, was replaced with a Fisher's exact test, which was used a goodness to fit test to confirm an association between the 2 groups and lacked detail in its explanation.

The results from Paone et al (1998) demonstrate that mortality and LOS were higher for the elderly group and they also had higher incidences of RBC transfusion, AF and the overall rate of complications. On multivariate analysis of preoperative variables, age, female gender, hypertension, COPD, IABP and BSA were significantly related to LOS. However, following the addition of postoperative variables, age was only marginally significant and it was found that RBC transfusion and the development of AF were the strongest predictors for increased LOS, alongside IABP and pneumonia ($p<0.001$) as discussed by the authors. They concluded that increased LOS for elderly patients is attributable to other factors suggesting that increased age is not a predisposing factor, which is contrary to other studies. Although the findings of this study can be applied to the local population, the small sample of elderly patients together with the lack of clarity of statistical analysis reduced the CASP score to 7.

The studies included in this review have demonstrated the variation within the definition of 'elderly' to be problematic, with some papers using 70 years as the definitive level, and others using 75 years or older as their selection. Despite this, there is consistent evidence within the literature to suggest that elderly patients are a greater risk of morbidity and mortality and increased LOS than their younger equivalents. Although there is evidence against this, suggesting particularly that mortality rates for elderly patients are acceptable. Furthermore, it is also important to consider if co-morbidities increase with age, perhaps 'elderly' patients would benefit more from a cardiac surgical procedure. Overall, the studies reflect increased age as a significant risk factor for complications following cardiac surgery.

2.4.5 Risk Factor: COPD

COPD has been frequently investigated for its influence in relation to adverse outcome following cardiac surgery. Cohen et al (1995) sought to evaluate the effects of COPD on patients undergoing cardiac surgery and examined the patterns for morbidity and mortality. 651 patients having CABG surgery during June, 1991 to June, 1993 were included in the study. Of the sample, patients were allocated to Group I if they had significant COPD (n=37) or to Group II which consisted of matched controlled subjects, matched for age, gender, ejection fraction and date of operation (n=37). The primary outcomes measured were valid and objective; LOS on ICU, total hospitalisation, morbidity and 30-day mortality. The patients included in Group I with severe COPD had to have been actively treated and followed up for COPD in a pulmonary clinic, together with evidence on CXR and PFT's. The basis to determine 'severe COPD' was based upon laboratory and radiological data. The chest roentgenograms taken preoperatively and at the last follow up were interpreted by a radiologist unfamiliar with the patients clinical status, thus reducing bias by a single-blinding procedure. All procedures were applied to both groups. The variety of statistical analysis performed was appropriate and justified, as the sample size was too small for a regression analysis. Patients were followed up in a clinic up to 16-months mid-term follow up, however, at the time there was a shift in focus mainly to QOL and physical status and not physiological parameters, which appeared earlier on in the study period.

Group I patients with severe COPD, had a lower FEV1, lower O2 tension and higher CO2 tension. This group was also found to have a longer hospital stay, 8.1 ± 3.6 days vs. 6.6 ± 1.7 days ($p=0.0236$). Additionally, group I patients had a longer ICU stay (2.64 ± 0.9 vs. 1.23 ± 0.49; $p=0.0001$), and required prolonged intubation and reintubation and significant arrhythmias. Also more patients died in Group I ($p=0.0271$).

The findings from Cohen et al (1995) suggest that the results from patients with severe COPD were not favourable. However, they do conclude that the main cause for morbidity and mortality was the development of postoperative arrhythmias and put forward that the indication for CABG in this group of patients be restricted. Despite the small sample size, the study was granted a CASP score of 10 out of 10.

In a latter study intending to determine the impact of different stages of COPD on early surgical outcomes in patients undergoing primary isolated non-emergent CABG. Saleh et al (2012) performed a retrospective analysis of a series of 13, 638 consecutive patients between April, 1997 and September, 2010. 2421 patients were excluded due to lack of spirometric data, therefore, 11, 217 patients were included in the study. The primary outcome was early mortality, defined as death within 30-days postoperatively and the secondary outcomes were the need for inotropic support or IABP, renal failure, MI, AF, re-exploration for bleeding, stroke and sternal wound infection together with PMV, defined as >72 hours postoperative ventilation.

Patients were allocated to one of 3 groups based upon PFT's: Group 1, classed as normal or mild COPD, FEV1 ≥80% predicted (n=9417); Group 2, moderate COPD, FEV1 <80% predicted (n=1535); Group 3, severe COPD, Fevl <50% predicted (n=265). The definitions of COPD are more precise, based on spirometry, than the laboratory and radiological data used to determine COPD in the previous paper by Cohen et al (1995). However, there was no evidence of blinding in this study, particularly for the interpretation of spirometry data. However, the statistical analysis and follow-up procedures were appropriate and comprehensive.

Early mortality rates were found to be 1.4%, 2.9% and 5.7% across the 3 groups respectively ($p<0.001$). This was confirmed on multivariate analysis which demonstrated that severe COPD to be significantly associated with early mortality ($p=0.01$). Also there was a consistent trend noted of increasing postoperative complications with advancing COPD. Both of these findings are parallel to that reported by Cohen et al (1995). Interestingly, as highlighted by the authors, 14.1% of patients with moderate to severe COPD on spirometry, had no history of pulmonary disease on referral for surgery. Subsequently, this has a potential impact on underestimating the prevalence of COPD in patients undergoing CABG surgery. As noted previously, this paper also scored10 out of 10.

In this review, the robust studies analysed put forward COPD as a significant risk factor for mortality and morbidity and the development of postoperative complications. Both studies have noted more complications with advancing COPD. However, they were both focused on CABG surgery, and the findings in relation to other surgical procedures may differ. It is important to consider the value of spirometric data, as suggested to be a prognostic marker in patients undergoing CABG surgery, particularly for those patients unaware of their pulmonary disease.

2.4.6 Risk Factor: Smoking

Smoking is a frequently occurring risk factor within the literature on cardiac surgery, mainly for its recognised association with coronary heart disease. In order to determine the impact of smoking on patients undergoing CABG surgery, Al-Sarraf et al (2008) set out to assess the effects of smoking on mortality and postoperative complications. They performed a retrospective review based at a single institution, which included 2587 consecutive patients having isolated CABG surgery from 2000 to 2007. Based upon their smoking status, patients were stratified into 3 groups: current smokers (n=473); former smokers defined as those who quit smoking more than 4 weeks prior to surgery (n=1346) and non-smokers (n=748). All patients were included and had an equal chance of inclusion therefore there was no evidence of selection bias. The main outcome was operative mortality, which was a valid and reliable measure, together with in-hospital mortality, postoperative morbidity, LOS in ICU and in hospital.

The statistical analysis included multiple logistic regression and the effects of smoking on each outcome variable was analysed by adjusted odds ratio after accounting for confounding factors. The CASP assessment score for this paper was reduced when examining the follow-up of patients as it was difficult to determine the duration of follow-up. Furthermore, influencing the CASP score was the in-hospital mortality outcome data. Although this usually suggests death within 30-days postoperatively, the criteria for this study was all deaths within the same admission following cardiac surgery, regardless of LOS. This appears obscure in comparison to a consistent valid outcome of 30-days which appears standard within the literature.

The main result from this study is that current smokers had higher rates of PPC's than ex-smokers and non-smokers; 30.1% vs. 23.3% vs. 19.9% ($p<0.001$). Rates of other complications, LOS and mortality did not differ between the groups. The findings are applicable to the local setting, and puts forward smoking as a significant risk factor for the development of PPC's. This paper achieved a CASP score of 8.

A study performed by Ngaage et al (2002) focused on smoking history and its impact on respiratory outcome after cardiac surgery, and evaluated the preoperative smoking habits of patients and their PPC's. They conducted a retrospective cohort study to obtain comparative rates of PPC's between cigarette smokers, ex-smokers and non-smokers, but also to determine the duration of mechanical ventilation and its impact on the rate of PPC's across the 3 groups. The authors recognised that literature surrounding the effects of smoking on the length of intubation was scarce. 2163 patients undergoing elective cardiac surgery between 1993 and 1999, were included. The proportions of cardiac surgical procedures are as follows: CABG surgery accounted for 73% (n=1579), valve surgery for 17.2% (n=372) and combined CABG and valve surgery for 9.8% (n=212). Their exclusion criteria was COPD, NYHA >3, octogenarians, off-pump surgery, emergency or redo surgical patients. Of the 4672 patients who had cardiac surgery during the timeframe, 2163 were included in the study. Patients were allocated to 3 groups: non-smokers (40.7%), ex-smokers (49.7%) and smokers (9.6%). The criterion for group allocation was universal which provided a greater chance of inclusion in the study. The outcomes used were the duration of postoperative mechanical ventilation, LOS in ICU and in hospital, which are clear objective measures, and also PPC's which were clearly defined in the methodology. Multivariate analysis was performed with the variables to control for the potential effect of modification. The follow-up of patients lacked clarification as it was over the length of admission.

The results demonstrated that PPC's were twice as frequent in smokers as non-smokers and ex-smokers, 29.5% vs. 13.6% vs. 14.7% respectively. Furthermore, smokers required a longer length of intubation, although this failed to reach a level of statistical significance. The authors concluded that active smokers have a comparatively poorer postoperative respiratory outcome after cardiac surgery, and particularly are at highest risk for the development of PPC's beyond 6 hours of mechanical ventilation ($p<0.002$). This additionally suggests the duration of mechanical ventilation has a direct impact on the development of PPC's. The findings of this study are supportive to that from Al-Sarraf et al (2008) and also achieved a CASP score of 8 out of 10.

Similarly to the previous study, Jones et al (2011) planned to assess the effect of preoperative smoking status on in-patient outcomes following adult cardiac surgery. By conducting a retrospective observational study, a cohort from a 5 year period ending March, 2007 that included all cardiac patients admitted to a single institution. Data was collected in line using electronic database, which was subjected to regular external audit. All current smokers were identified and an equal number of non-smokers were chosen at random by the software. This reduced any bias in their selection methods and ensures all patients had an equal chance for inclusion. Preoperative co-morbidity, intraoperative factors and morbidity and mortality outcomes were analysed in the two groups; smokers (n=554) vs. non-smokers (n=554). However, there was no mention of blinding procedures, and the follow-up of patients was unclear.

Logistic regression analysis was performed using a binary logistic model to assess the contribution of each demographic and comorbidity factors, whilst accounting for confounding factors. However, as discussed by the authors, in the non-smoking group there are likely to be patients included that have only recently stopped smoking, which may influence the results. It was found that 10.8% of patients were smokers, which had a tendency for higher in patient mortality, 4.3% vs. 2.3% although this was not statistically significant at $p=0.067$. Among those patients aged over 70 years and actively smoking, there were significantly higher rates of PPC's demonstrated, 24.7% vs. 8.2% ($p<0.002$), and also new renal replacement therapy and infections were evident for this group and also statistically significant. With regards to clinical outcomes, those patients currently smoking had longer ICU stay (6.2 vs. 2.8 days, $p=0.002$), more ICU readmissions (19.8 vs. 5.2%, $P<0.0002$) and a higher in-patient mortality rate (14.8 vs. 2.1%, $p<0.0001$). These findings further add weight to the previous study to conclude smoking to be a significant risk factor.

In relation to smoking as a risk factor for the development of postoperative complications, the literature contained in this review consistently has strengthened the association between smoking as a strong predictor for pulmonary complications and adverse outcome following cardiac surgery.

2.4.7 Risk Factor: Obesity

Obesity is another risk factor renowned for its association with coronary artery disease, and is a predominant factor within surgical and anaesthetic risk assessment procedures. Moulton et al (1996) addressed a clearly focused hypothesis that obese patients would not be at higher risk for operative mortality, pulmonary complications, sternal wound infections, stroke or pulmonary embolism (PE) following cardiac surgery. All patients at a single institution that underwent cardiac surgical procedures requiring CPB during January, 1991 and December, 1993 (n=2299) were included. Patients were divided into 2 groups: obese with a BMI >30, and non-obese. Therefore no randomisation occurred, and the same methods were applied to both groups. Obesity, or BMI was the main objective measurement, and recorded outcomes were operative mortality, defined as in-hospital death, arrhythmias, ARDS, PE, renal failure, wound infection, sepsis, PMV, ICU stay and hospital stay. Numerous confounding factors were addressed in the multivariate logistic regression to control for the confounding effects for other risk variables. The authors did not provide any precise details surrounding the follow-up of the patients' procedure; therefore this remains unclear and reduced the scoring of this paper.

Of this cohort, 25% of patients were classed as obese, and the results demonstrated that obesity was found to be a risk factor only for sternal wound infection ($p<0.01$), leg wound infections ($p=0.05$) and atrial dysrhythmias ($p=0.04$). Obesity did not predispose patients towards increased pulmonary complications or deep sternal wound infection. It was concluded that obesity was not a risk factor for adverse outcome following cardiac surgery. This paper reached a score of 8 out of 10 in the CASP assessment, with its comprehensive data profiles, and numerous confounding variables that were taken into consideration to confirm the findings that can be applied locally.

In a more recent publication, those patients who are extremely obese with a BMI of greater than 40, were assessed for their perioperative risks by Wigfield et al (2006). A retrospective analysis was performed that included 1920 consecutive cardiac surgical patients from January, 1999 to May, 2004 and excluded surgery for cardiac transplantation and ventricular assist devices. All data was collected based upon the Society of Thoracic Surgery (STS) guidelines and definitions including preoperative characteristics, operative information and outcomes of operative death, 30-day mortality, LOS on ICU and overall LOS were analysed. Patients were allocated to 3 groups: non-obese with a BMI 20-30, Obese with a BMI of >30-40 and extreme obese with a BMI >40. Although confounding factors were identified in the study, the authors failed to undertake a multivariate analysis or regression modelling to address this. Furthermore, the follow-up of the patients being 30 days, as stated previously, could be viewed as being too short in duration.

Patients who were extremely obese with a BMI of >40 were developed significantly greater rates of postoperative complications overall than the other groups, new stroke, renal failure requiring dialysis and atrial fibrillation ($p=0.04$). Interestingly, the development of pneumonia postoperatively did not differ across the BMI categories. Extreme obese patients were found to have increased LOS (11.4 days vs. 9.6 days, $p \leq 0.01$), rate of renal failure (14.3% vs. 5%, $p=0.003$) and prolonged ventilation (39% vs. 23.5%, $p=0.003$) compared to the non-obese group. The authors concluded that cardiac surgery can be performed without an increase in perioperative and 30-day mortality, although the overall complication rates and LOS for extremely obese patients was greater. It is important to address the findings from this study in the context that they are presented, as very few of the local population will undergo cardiac surgery with a BMI of >40, and therefore the results are difficult to apply to the local setting. This paper attained a CASP score of 8.

The literature suggesting an increased BMI as a risk factor for complications following cardiac surgery appears fragmented. The two studies included in this review had comparable CASP scores of 8 out of 10 and do provide valuable information on obesity, however dispute any suggestions that obesity is a pertinent risk factor for the development of PPC's.

2.4.8 Risk Factor: Heart Failure

The demands of the cardiovascular system to pump blood around the body to adequately perfuse the surrounding tissues requires an efficient pump mechanism of the heart. When this pump decreases in strength, the ejection of blood expelled from the heart to vital organs is consequently reduced, as evident in Chronic Heart Failure (CHF), which has been suggested to compromise pulmonary function.

In order to understand the influence of heart failure alone on the lungs and chest wall functioning, Johnson et al (2001) sought to assess pulmonary function in patients with a history of stable, reduced LV function in relation to smoking history and cardiac surgery. This U.S based study, performed a retrospective analysis and recruited patients from a heart failure clinic from 1994 to 1998 that included patients with histories of dilated and ischaemic cardiac pathological conditions with ejection fractions ≤35% and excluded patients with a BMI of >35. Patients were allocated to one of five groups, as outlined below:

- Group 1 (n=78): CHF, non-smokers without CABG
- Group 2 (n=46): CHF, non-smokers with CABG
- Group 3 (n=40): CHF, Smokers, without CABG
- Group 4 (n=48): CHF, Smokers with CABG
- Group 5 (n=112) were a control group that contained patients that were matched for age and gender with a history of CAD without LV dysfunction, i.e. LVEF>50% or smoking.

The main outcome measure was PFT's, including maximal voluntary ventilation maneuvers and TTE, performed as standard, robust, clinical measures on all patients, though there was no evidence of blinding. Statistical analysis was performed using analysis of variance and post hoc analyses using *t* tests. Consequently, it could be argued that this analysis was not sufficient to account for confounding factors that may have influenced the outcome.

All groups with CHF were found to have reduced lung volume, especially Total Lung Capacity (TLC), Vital Capacity (VC) and expiratory flow, which was statistically significant ($p<0.05$). Interestingly, the addition of CABG surgery had no influence on lung volume findings in smokers, but resulted in a tendency to lower TLC and VC in non-smokers. Smokers with CHF were found to have reduced expiratory flow compared to non-smokers suggesting the additive complication of smoking ($p<0.05$). In this study, no association between LV size and pulmonary function was discovered, although there was a weak correlation LV function and lung volumes. It was concluded that patients with CHF present primarily with restrictive lung changes, and with the addition of smoking that causes a further reduction in expiratory flow. However, this paper provides evidence of the association between heart failure and pulmonary function, and obtained a CASP score of 7 out 10.

With recognition of the impact of heart failure on pulmonary function, in particular the strength of respiratory muscles, with specific reference to the diaphragm, Bastos et al (2011) aimed to determine the influence of preoperative respiratory muscle strength on postoperative pulmonary complications, in patients with heart failure. They completed a prospective cohort study, longitudinal in design that included individuals with compensated systolic/diastolic heart failure admitted for elective cardiac surgery. Individuals were excluded with any risk factor that may have influenced the results of the assessment of respiratory muscle strength, e.g. drugs, malnutrition, BMI, CVA, neuromuscular disease. Patients with risk factors for PPC's including pulmonary disease or active or ceased smoking within 2 months of surgery were excluded. Patients were obtained by convenience sampling and assessed for heart failure using the Boston criteria, which is a valid outcome measure followed by an preoperative respiratory muscle strength assessment using a pre-calibrated manometer. Patients were divided into 2 groups, Group A (n=21): composed of patients with normal respiratory muscle strength and Group B (n=19) which consisted of patients with reduced respiratory muscle strength. Following this, both of the groups received the same postoperative physiotherapy intervention, as per protocol. All patients during the timeframe had an equal chance of inclusion, and the same procedures of testing were applied to both groups. The pertinent description of the methodology enhances the reliability and replication of the protocol used.

Variables were collected preoperatively including anthropometric measurements, clinical features such as heart rate, blood pressure, NYHA, LVEF and perioperative length of surgery and CPB time. Postoperatively outcome measures studied were length of ICU stay and hospital stay, pain assessment using a numerical scale of measurement, and the presence of PPC's measured according to detailed definitions presented. The independent data was analysed using student t-tests, and for comparing groups when analysing categorical variable, the Chi-squared and Fisher exact tests were used. As found in the paper by Johnson et al (2001), the statistical analysis was insufficient. Furthermore, regarding the follow-up in this study, patients were followed up from admission until hospital discharge or death by the same researcher, however this in unclear if this is contained within the data for LOS.

Of the patients in group A, 19% of patients had PPC's compared to 31.6% in group B, however this was not statistically significant. Additionally, no difference was found between groups for ICU stay or total hospital stay in this study. The authors conclude that preoperative muscle dysfunction in patients with heart failure undergoing cardiac surgery does not appear to influence the incidence of PPC's. The authors state in their discussion their criteria for diagnosing PPC's was based solely on clinical signs and not on radiological evidence, which may have influenced the results. It is also important to consider another point raised which is the disparity that exists within the literature for a diagnosis of PPC and how this maybe an explanation for the variance of incidence's across studies. This paper was awarded a CASP score of 8.

It has been demonstrated that there appears to be an influence of heart failure on pulmonary function. If a relationship exists between reduced respiratory muscle strength and LV dysfunction, it has not been found to influence the development of PPC's in this review. Although, as discussed this may be attributed to the disparity in the definition of PPC's. However, this evidence does feature a clinical importance of considering respiratory muscle strength in patients undergoing cardiac surgery.

2.5 Summary

The aim of this review was to explore evidence relating to risk factors and preoperative characteristics as predisposing factors for PPC's. This information would be beneficial in gaining an understanding of PPC's in relation to the context of the aim and objectives of the thesis. Further, it was imperative to ascertain if any prediction model exists within the literature that could inform current physiotherapy practice.

The evidence has demonstrated that over recent years various efforts have been made to predict PPC's following cardiac surgery, some predicting more generalised pulmonary complications and others, more specific in the prediction of pneumonia or respiratory failure postoperatively. Much of this work has been based upon patient characteristics, intra-operative and postoperative risk factors, however, the vast majority of studies are applicable only to those undergoing isolated CABG surgery. Consequently, no suitable prediction model was discovered to screen patients for factors that would predispose patients for the development of PPC's. Although, the research included in this review has demonstrated specific risk factors to be consistently highlighted in the literature and are proposed to be predisposing factors for the development of PPC's. These include age, gender, COPD, smoking, obesity and LV function, which have been independently examined as influential factors. The purpose of identifying and detailing these causal factors for PPC's will assist in the design of the proposed service evaluation of the local cardiac population. Therefore, these patient characteristics will serve as preoperative variables against which the population will be defined. This understanding is essential to inform physiotherapy services for the local community.

Whilst this chapter has specifically examined these risk factors, it has not provided information relating to the wider context in determining morbidity and mortality postoperatively. Neither has the role of physiotherapy strategies to avert PPC's been examined. This step would provide a more in-depth understanding of the subject. Therefore, it is now prudent to examine these complications in a broader context of postoperative recovery and to consider potential physiotherapy based strategies aimed at the reduction of PPC's.

3.0 Narrative Review

Post-Operative Complications in Determining Morbidity and Mortality Following Adult Cardiac Surgery

3.1 Introduction

There have been various endeavors to examine risk factors for the prediction of adverse outcome including PMV, reintubation, morbidity and mortality. Numerous independent predictive variables have been proposed to be associated with an increased risk of postoperative complications following cardiac surgery, including, advancing age (Arom et al, 1995; Rady et al, 1997), diabetes mellitus, cigarette smoking (Hulzebos et al, 2003) and NYHA Class IV (Engoren et al, 1999). More specifically a history of pulmonary impairment has been associated with an increased risk of pulmonary morbidity (Cohen et al, 1995) and adverse surgical outcome including early mortality (Saleh et al, 2012). Furthermore, in relation to an increased risk of morbidity and mortality following adult cardiac surgery is PMV, proposed to be associated with nosocomial infections (Fagon, 1996). Understanding these determinants of prolonged LOS and major morbidity, facilitates the planning of resources in ICU (Maria, 2005). It could therefore be argued that this knowledge could also assist in the planning of vital physiotherapy resources.

3.1.1 Rationale

The Systematic Review undertaken in Chapter 2.0 yielded an evidence base surrounding the potential risk factors including preoperative characteristics for the development of PPC's. This evidence has provided an insight into the nature and determinants of PPC's, however the development of this complication within the context of the overall postoperative recovery following cardiac surgery is not yet known. This knowledge will permit a greater understanding into the nature and causal factors of PPC's, as set out in the overall aim of the thesis, as well as recognising the bearing of this complication on the service. Additionally, the potential for physiotherapy based interventions in managing PPC's has not yet been explored. It is necessary to gain a wider understanding of PPC's, not only in terms of causative factors but also in determining how frequent these complications occur in comparison to other more generalised or specific complications. This is crucial in examining PPC's in the wider context and assessing the impact on the cardiac surgery service as a whole including mortality and postoperative morbidity such as LOS, PMV and Readmission to ICU. Furthermore, it is paramount to review the evidence relating to physiotherapy treatment interventions that are thought to address PPC's, which could potentially inform physiotherapy services locally. This is a key stage in addressing the aim and objectives of this thesis.

3.2 Aim

The aim of this review is to explore the evidence base surrounding postoperative complications following cardiac surgery. The incidence of postoperative complications in particular PPC's and their impact on clinical outcome thus determining morbidity and mortality will be determined. Crucially, the provision of physiotherapy treatment initiatives proposed to avert PPC's will be examined.

3.3 Methodology

3.3.1 Search Strategy

The identification of the relevant literature was undertaken from the search strategy and electronic searches as utilised in the systematic review (Chapter 2.0). The search history and key terms used can be found in Table 6.

3.3.2 Paper Selection

Of the 314 papers yielded by the initial search strategy, 18 studies were excluded from the systematic review and were relevant to the aim of the narrative review. These 18 articles were either not eligible for inclusion, or were not of sufficient quality for inclusion in the systematic review. Although, it was of the opinion that they were extremely relevant to the overall research objectives. Subsequently, it was agreed that their content not be scored but read and appraised in a narrative review.

3.4 Results

The search history and number of papers retrieved with the key words and combinations can be found in Table 6. The table below summarises the papers included in the review.

Table 9: Summary of articles eligible for inclusion in the narrative review

Authors	Title
Sheppard, MN. (2012)	Complications following cardiac coronary artery bypass surgery
Laizo, A. et al (2010)	Complications that increase the time of hospitalization at ICU of patients submitted to cardiac surgery
Kollef, MH. et al (1997)	The Impact of Nosocomial Infections on Patient Outcomes Following Cardiac Surgery
Gaynes, R. et al (1991)	Risk Factors for Nosocomial Pneumonia After Coronary Artery Bypass Graft Operations
Leal-Noval, SR. et al (2000)	Nosocomial Pneumonia in patients undergoing heart surgery
Spivack, SD. et al (1996)	Preoperative Prediction of Postoperative Respiratory Outcome
Bando, K. et al (1997)	Determinants of Longer Duration of Endotracheal Intubation After Adult Cardiac Operations
Bardell, T. et al (2003)	ICU readmission after cardiac surgery
Vohra, HA. et al (2005)	The predictors and outcome of recidivism in cardiac ICUs
Litmathe, J. et al (2009)	Predictors and Outcome of ICU Readmission after Cardiac Surgery
Johnson, D. et al (1996)	The Effect of Physical Therapy on Respiratory Complications Following Cardiac Valve Surgery
Brasher, P. et al (2003)	Does removal of deep breathing exercises from a physiotherapy program including preoperative education and early mobilisation after cardiac surgery alter patient outcomes?
Urell, C. et al (2011)	Deep breathing exercises with positive expiratory pressure at a higher rate improve oxygenation in the early period after cardiac surgery – a randomised control trial
Crowe, JM and Bradley, CA (1997)	The Effectiveness of Incentive Spirometry With Physical Therapy for High-Risk Patients After Coronary Artery Bypass Surgery
Dias, CM. et al (2010)	Three physiotherapy protocols: Effects on pulmonary volumes after cardiac surgery
Stiller, K. et al (1994)	Efficacy of Breathing and Coughing Exercises in the Prevention of Pulmonary Complications After Coronary Artery Surgery
Eales, CJ. et al (1995)	Evaluation of a single chest physiotherapy treatment to postoperative, mechanically ventilated cardiac surgery patients
Patman, S. et al (2001)	Physiotherapy following cardiac surgery: Is it necessary during the intubation period?

3.5 Discussion

3.5.1 Post-Operative Complications and Clinical Outcome

Sheppard (2012) reported on an autopsy series of 468 postoperative cardiac cases and showed that death was attributable to cardiac complications in 49.8% of cases, respiratory in 8.3%, cerebral in 6.4%, abdominal in 4.7%, multi-organ failure/sepsis in 14.9%, pulmonary embolism in 6.6%, associated with the procedure in 8.3% and attributable to other complications in 0.9% (Sheppard, 2012).

Postoperative complications can be cardiac in origin, for example, cardiac arrest, a surgical site infection (Kollef et al 1997; Laizo et al, 2010; Sheppard, 2012), pericardial effusion or tamponade (Bardell et al, 2003; Vohra et al, 2005; Sheppard, 2012), postoperative arrhythmias (Bardell et al, 2003; Sheppard, 2012), haemorrhage (Vohra et al, 2005; Sheppard, 2012), MI and cardiac failure (Bardell et al, 2003; Vohra et al 2005). Neurological complications can be attributable to cerebral infarction (Sheppard, 2012); gastro-intestinal complications can be as a result of mesenteric ischaemia (Sheppard, 2012); pulmonary complications can be resulting from lung damage directly from the development of adult respiratory distress syndrome or from respiratory infection (Kollef et al, 1997; Bardell et al, 2003; Vohra et al, 2005; Laizo et al, 2010; Sheppard, 2012) or ventilator-associated pneumonia (VAP). Other complications include venous thromboembolism, dissection of aorta, urinary tract infection and sepsis (Kollef et al, 1997; Bardell et al, 2003; Vohra et al, 2005; Sheppard, 2012)

In examining the complications that occur during the immediate postoperative period following cardiac surgery, Laizo et al (2010) undertook a retrospective evaluation of the medical records of 85 patients during a 2-year period from March to May 2009. The aim of the study was to identify those complications that increase the LOS in ICU following a variety of cardiac surgical procedures. In this study, prolonged ICU was considered more than 5 days, which applied to 16.47% (n=14) of the study cohort.

The results of the univariate analysis performed showed that the mean age was 59.09 ±14.04 years and the duration of ICU stay was 1 to 21 days with a mean LOS of 4.16 ± 3.76 days. The results demonstrated that the average LOS was not related to the type of surgical procedure. With regards to the postoperative complications, the study revealed a prolonged LOS in ICU following cardiac surgery were mainly due to those factors relating to respiratory function and metabolic disorders. However, the authors failed to undertake a multi-variate analysis to determine the relationship between the co-morbidities and LOS in ICU, thus cannot account for discrete confounding variables. Furthermore, the small sample cohort in this study, i.e. 14 patients over the 2-year study period together with the ambiguous definition of prolonged LOS on ICU makes it difficult to apply the findings to the current setting.

3.5.2 Complications due to Hospital-Acquired Infections

Kollef et al (1997) set out to determine the incidence of hospital-acquired infections following cardiac surgery. It is proposed that cardiac surgical patients are at increased risk for the development of nosocomial infections due to multiple surgical wounds, the use of invasive monitoring devices and the requirement for prophylactic or empirical antibiotic therapy (Kollef, 1993). Using a prospective cohort study including 605 consecutive patients during an 11-month period between August, 1995 and June, 1996, all patients undergoing cardiac surgery, including CABG surgery in isolation, CABG with or without an accompanying valve replacement and other surgery involving the thoracic aorta were included. Hospital mortality was the main outcome, and secondary outcomes investigated were LOS on intensive care, duration of mechanical ventilation, development of clinical sepsis and multi-organ dysfunction. Nosocomial infections, i.e. urinary tract, bloodstream and wound infection were defined according to the criteria set by Centers for Disease Control and Prevention. Patients were evaluated for nosocomial pneumonia during mechanical ventilation and 48 hours following extubation to confirm a ventilator-associated pneumonia (VAP).

In this study, 131 patients (21.7%) acquired at least one nosocomial infection following cardiac surgery. VAP was the most common infection (n=59) followed by urinary tract (n=54), wound (n=45) and bloodstream infections (n=21). The results of the multivariate analysis demonstrated that female gender, the duration of mechanical ventilation, the administration of empiric postoperative antibiotics and the duration of urinary catheterisation were independent risk factors for the development of nosocomial infections (Kollef et al, 1997). In relation to mortality, those patients who developed a nosocomial infection had significantly greater mortality rate of 11.5%, compared to 3.2% for those patients without ($p<0.001$). More specifically, for those patients with VAP, the mortality rate of 23.7% was significantly greater than other nosocomial infections ($p=0.012$).

Additionally, those infected patients had significantly longer LOS in ICU (7.8 ± 8.0 vs. 2.3 ± 1.8 days; $p<0.001$, and longer duration of mechanical ventilation (6.0 ± 8.0 days vs. 1.4 ± 1.1 days; $p<0.001$) and were significantly more likely to develop multi-organ dysfunction ($p<0.001$) compared to those without a nosocomial infection.

This prospective study has provided information based on a large sample cohort, and its findings are in agreement with Laizo et al (2010) with respect to the main postoperative complication that influences clinical outcome are pulmonary in origin. However, the statistical analysis in this study provides a greater weight to the influence of baseline and surgical characteristics of the cohort and the impact of nosocomial infections on clinical outcomes following cardiac surgery.

Although the authors acknowledged there is a limitation to establishing a direct causal link between nosocomial infections and increased hospital mortality, they did find an increased LOS for infected patients. They advocated strategies to reduce the infection rates that would achieve shorter hospital stays and reduce the financial implications of these complications (Kollef et al, 1997).

According to Gaynes et al (1991), the development of nosocomial pneumonia is one of the most serious of all hospital-acquired infections. There are various studies that have made attempts in determining the risk factors for the development of nosocomial pneumonia in patients undergoing CABG surgery.

Similarly to Gaynes et al (1991), Leal-Noval et al (2000) aimed to determine the risk factors related to the presence of postoperative pneumonia in patients undergoing cardiac surgery. The study was conducted between January, 1993 and December, 1996. The positive diagnosis of nosocomial pneumonia was based upon clear objective markers including the presence of a new, persistent or progressive lung infiltrate on the chest radiograph and fever >38°c and clear parameters of leukocytosis. Of the 135 patients included in the study, 45 patients developed nosocomial pneumonia. Multivariate analysis, used to identify independent risk factors for acquiring nosocomial pneumonia, found an association with reintubation, the presence of a nasogastric tube, a transfusion of >=4 units of blood or treatment with broad-spectrum antibiotics.

The mortality rate in the group of patients with nosocomial pneumonia was significantly higher than the control group, who did not acquire pneumonia (51% vs. 6.7%, $p<0.01$). Additionally, those patients who survived nosocomial pneumonia had a significantly longer LOS in ICU than those unaffected (25 ±14.8 days vs. 5 ±5 days, $p<0.01$). These findings are in accordance with that reported by Kollef et al (1997), and one of the common features was the use of empirical antibiotics as one of risk factors reported to be associated with nosocomial pneumonia, as reported in both studies. However, the findings from Leal-Noval et al (2000) are based upon a small cohort of only 45 patients and are only representative of a surgical population undergoing CABG surgery only.

The development of postoperative complications following adult cardiac surgery, and in particular pulmonary complications have been linked to increased mortality and morbidity with an increased LOS on intensive care and considerable financial implications that are incurred (Kollef et al; 1997; Leal-Noval et al; 2000; Laizo et al; 2010). More specifically, and to a greater extent, in relation to adverse clinical outcomes, an influential factor in necessitating a prolonged LOS is prolonged mechanical ventilation (PMV).

3.5.3 PMV

Spivack et al (1996) recognised how the leading source of complications during the postoperative period following cardiac surgery has been respiratory, and set out to conduct an observational study to test the hypothesis of traditionally defined preoperative risk factors for predicting PMV after CABG surgery. They prospectively evaluated 513 consecutive patients undergoing CABG from April 1991 to March, 1992. Preoperative pulmonary evaluation including spirometry and arterial blood gas analysis, and preoperative cardiac parameters such as left ventricular function were also assessed. The main outcome measures were the duration of mechanical ventilation, the duration of ICU stay and mortality. Patients were excluded if PFT data was unavailable, or if they underwent combined CABG/valvular surgery as the authors explicitly state how the anesthesia techniques and timeframe differ to that of CABG surgery alone. Patients were then subdivided according to the urgency of surgery as follows: emergent, urgent or elective.

PMV was considered to be ventilation >48hours following surgery in this study, which is in conformity with the STS National Database Risk Stratification definition (Shroyer et al, 2003), and thus applicable to the current setting. The results of this study showed the incidence of PMV to be 8.3%, and mortality at 2.0%, which is considerably low compared to other studies. The results of the multivariate analysis showed the combination of reduced left ventricular ejection fraction together with selected preexisting comorbid conditions, such as angina, smoking, diabetes, congestive heart failure, to be modest risk factors for PMV. However, across all subgroups, reduced left ventricular ejection fraction was the only characteristic found to have a positive correlation in predicting PMV as an adverse clinical outcome. Therefore suggesting that PFT's, ABG parameters and pulmonary diagnosis do not contribute to the prediction of a complicated respiratory course following cardiac surgery. The authors do however recognise their shortcomings, as they discuss bias to be a possibility inherent with an observational study. Despite this, the incidence of PMV appearing low in this study, the impact on clinical outcomes is profound, as the authors suggest those individuals with a complicated postoperative course require intensive health care resources.

The findings from Spivack et al (1996) are similar to that reported by Bando et al (1997) who aimed to confirm the ability of PFT's to predict PMV and also to determine the risk factors that may be associated with PMV. They retrospectively reviewed the outcomes of 586 consecutive patients that underwent cardiac operations including CABG or valve procedures. Multivariate predictors of PMV were found to be priority of operation, congestive cardiac failure, renal insufficiency and recent MI, which is consistent with the predictors found by Spivack et al (1996). Also, in agreement, Bando et al (1997) failed to find a correlation between PFT's and PMV, and concluded that postoperative cardiac function and the occurrence of complications are more significant than PFT's in determining PMV following cardiac surgery.

The literature evaluated in this review so far has been predominantly based upon the primary stay on ICU following surgery, as this is often a pertinent feature when clinical outcomes are the main focus. Yet it is important to consider on the other hand, when a patient is discharged from ICU and clinically deteriorates, and requires an increased level of medical care, patients can be readmitted. Subsequently, the research into readmission is just as crucial as that determining prolonged LOS and adverse outcomes.

3.5.4 Readmission to ICU

Bardell et al (2003) investigated ICU readmission rates after cardiac surgery. They retrospectively reviewed the case notes for 2117 consecutive patients undergoing CABG surgery during January, 1999 to August, 2001. During this time, 3.6% (n=75) of patients were readmitted during the study period.

For the patients readmitted, the most common reason was due to respiratory failure, and this accounted for 47% of patients. It is noted that the patients readmitted due to respiratory reasons encountered respiratory distress and/or difficulty in clearing secretions, pneumothorax, aspiration, marked atelectasis, exacerbation of COPD among others. Additionally, 20% of patients were readmitted due to cardiac reasons, which included cardiac arrest, arrhythmias, angina, tamponade etc.

With regards to clinical outcomes, the overall mortality rate was 2.8%, which is less than that previously reported by Kollef et al (1997) and for those patients readmitted to ICU, this increased significantly to 17% ($p<0.0001$). The median ICU stay prior to discharge for the patients that were eventually readmitted was 6 ± 8.7 days, compared to 1 day, for patients that did not require readmission (Bardell et al, 2003). The multi-variate analysis using a step-wise logistic regression analysis highlighted preoperative renal failure and prolonged ventilation were the only independent predictors for readmission to the ICU after CABG surgery. However, the results of this study are only applicable for patients undergoing CABG surgery and not the other possible surgical procedures.

The authors put forward an understanding into the two clinical variables for ICU readmission including the increased risk of complications associated with preoperative renal failure, and how prolonged ventilation is associated with poorer outcome. It is recommended that clinicians consider methods of avoiding these complications to reduce the rate of readmission to ICU.

Likewise, Vohra et al (2005) studied 8113 consecutive patients who underwent CABG, valve replacement/repair or combined CABG and valve surgery between January, 1996 and December, 2003. Their aim was to determine the rate and principal reasons for readmission to ICU. In this study, for the 7717 patients that were discharged from ICU, 2.3% (n=182) were readmitted. As previously reported by Bardell et al (2003), the most common cause for readmission was respiratory complications requiring re-intubation and ventilation, which resulted in 54.9% (n=100) of readmissions to ICU. This is greater than 47% of the readmissions for respiratory problems found previously (Bardell et al, 2003). The respiratory complications encountered were hospital-acquired and aspiration pneumonia, retention of secretions and poor ventilatory reserve leading to hypoxia or ventilator failure. Additionally, in agreement with Bardell et al (2003), the second most common caused for readmission was complications that were cardiac in origin, such as cardiovascular instability, dysrhythmias and heart failure, accounting for 23.2% (n=42) of patients.

In terms of outcome, the mean LOS in ICU of patients that subsequently returned to ICU was 2.5 ± 3.4 days, compared to those patients who did not require a readmission and had a shorter ICU stay of 1.6 ± 2.2 days. In agreement with the findings from Bardell et al (2003), those patients readmitted to ICU has a significantly higher 30-day mortality rate of 32.4 % n=59) vs. 2.05% (n=155; $p<0.05$), and greater than reported previously. Multiple regression analysis in this study revealed that a previous history of MI, was the only independent preoperative risk factor associated with readmission ($p<0.01$). However, the authors highlight that during the primary ICU stay, respiratory problems, low cardiac output state, cardiac dysrhythmias, renal failure and re-exploration for bleeding were independent predictors. Also those patients who underwent combined CABG and valve surgery were found to have a greater risk of ICU readmission ($p=0.01$). The authors discuss an important concept how many of these patients are generally at higher risk for morbidity and mortality and specifically they have reduced left ventricular function and are in heart failure and consequently, are at greater risk for the development of complications postoperatively. Vohra and colleagues (2005) further explicitly stated the need for intensive respiratory physiotherapy for patients with respiratory complications, which is suggested to reduce morbidity and mortality but also to assist in the avoidance of readmission to ICU.

In a more recent publication, Litmathe et al (2009) reported an incidence of 5.9% of 3523 patients studied to have required ICU readmission after cardiac surgery. In accordance with the findings from Bardell et al, (2003) and Vohra et al (2005), the main reason for readmission were respiratory failure in 59% of cases, followed by cardiovascular instability, accounting for 25% of patients readmitted. The statistical analysis revealed independent predictors for readmission, were similar to that found previously, i.e. preoperative renal failure, mechanical ventilation greater than 24 hours, re-exploration for bleeding, and low cardiac output state. The authors conclude that there is a pertinent need to treat cardiorespiratory problems early based on those patients who exhibit predictive characteristics.

It appears as though, one of the common features amongst the literature surrounding the development of postoperative complications, the duration of intensive care stay, PMV and readmission to ICU, are respiratory/pulmonary complications. The literature discussed in this review has revealed that pulmonary complications are consistently found to be the most frequently occurring complication following cardiac surgery. Hence, it is clinically necessary to consider strategies to avert pulmonary complications, one of which to be considered is physiotherapy.

3.5.5 Physiotherapy in Cardiac Surgery

In relation to the development of pulmonary complications, historically, physiotherapy has been provided to patients undergoing cardiac surgery. The aim of physiotherapy regimes include improving pulmonary function and the avoidance of the development of pulmonary complications such as atelectasis and pneumonia. A variety of respiratory physiotherapy techniques are available including breathing exercises, incentive spirometry, coughing, positioning and early mobilisation for those patient who are spontaneously breathing. Other maneuvers such as manual hyperinflation, manual techniques and suctioning are utilised for patients who are intubated and ventilated following cardiac surgery. Prophylactic respiratory physiotherapy treatment regimens have been delivered preoperatively and/or postoperatively, although traditional clinical practice often varies among centers.

As previously discussed in Chapter 1.7, the clinical practice surveys demonstrate an overview of physiotherapy service provision and a general consensus in the selection of the physiotherapy treatment techniques. Although variability amongst clinical protocols relating to assessment and treatment maneuvers were evident, the specific techniques aimed at reducing postoperative pulmonary complications appears speculative.

Johnson et al (1996) conducted a Randomised Control Trial (RCT) to determine if higher personnel intensive chest physiotherapy can prevent atelectasis that routinely follows cardiac valve surgery. 78 patients were randomised into 2 groups either receiving low intensity treatment (n=41) including early mobilisation and sustained maximal inflations, or to a higher intensity treatment group (n=34) who received treatment that consisted of early mobilisation, sustained maximal inflations and single handed percussion. The outcomes used were extent of atelectasis was scored and length of ICU and hospital stay together with economic costing's were recorded. The results demonstrated similar extent of atelectasis, ICU and hospital length of stay regardless of treatment.

However, only a single intervention for the treatment of atelectasis was investigated and no physiotherapy was withheld from the control group, which may make it difficult to generated comparisons to other literature. Additionally, there were no identification of preoperative risk factors, although this was not the focus of the study. Although, on a theoretical level, the authors propose the benefit of specific physiotherapy manoeuvres to increase surfactant production thus increasing lung compliance and systemic oxygenation and increasing regional inflation to facilitate the re-expansion of atelectasis. Despite this, when investigating the economic considerations for the high intensity intervention group, time and costs were significantly greater and labour intensive. Therefore, although the clinical efficacy of some specific treatment techniques were unproven, the prescription of high intensity physiotherapy adds significantly to patient costs and is paramount to consider when evaluating such techniques and services in the future.

In comparison, Brasher et al (2003) aimed to establish whether the removal of a regime of deep breathing exercises from postoperative physiotherapy management altered patient outcomes following elective open heart surgery. Patients were randomised into 2 groups, group 1 (Intervention), patients received an assessment, positioning, mobilisation and deep breathing exercises (DBEX'S) and in the control group (group 2), patients received only assessment, positioning and mobilisation. The author's specifically investigated the incidence of PPC's and postoperative length of stay, pulmonary function and oxyhaemoglobin saturation (Spo2). The authors explicitly cites a definition of a PPC as "a pulmonary abnormality that produces identifiable disease or dysfunction that is clinically significant and adversely affects the clinical course"

(O'Donohue, 1992). The main results of the study shows no significant difference between the 2 groups were found in relation to the primary outcome variables and the authors concluded that the removal of DBEX's from a patients physiotherapy management had no deleterious effect on outcome. However, in the current study, there was a low incidence of PPC's for both the intervention group (4.3%) and the control group (2.6%) and for those individuals who developed PPC's, their mean LOS was greater, which reflects the impact of PPC's on outcomes. Additionally, those patients who developed PPC's would require more physiotherapy input, and those individuals in the breathing exercise group necessitated a significantly higher physiotherapy time. This is in agreement to that found by Johnson et al (1996) in their discussion of allocation of physiotherapy resources may require a redistribution of resources. Consequently, this study makes no comment on the efficacy or otherwise of physiotherapy after open heart surgery.

Urell et al (2011) intended to determine whether or not the implementation of a higher rate of DBEX's with positive expiratory pressure in the initial phase after cardiac surgery would affect oxygenation and pulmonary function. The sample size of 181 patients were randomised into 2 groups; a treatment group (n=89) performing deep breaths hourly on the first and second postoperative day, and a control group (n=92) who were instructed to perform 10 breaths hourly during the same timeframe. The primary outcome measures were arterial blood gas analysis and pulmonary function, evaluated by spirometry. In order to address 'blinding', the 2 assessors for spirometry were unaware of the group allocation. The main results of this study indicate that patients performing a higher rate of DBEX's in the initial postoperative period had significantly increased oxygenation. One of the strengths of this research is its clinical relevance as the authors focused on the first and second postoperative days, which is considered a critical phase in the avoidance of re-intubation in clinical opinion. This is in agreement with the clinical practice surveys (Overend et al, 2010; Reeve and Ewan, 2005; Tucker et al 1996). The authors propose alveolar recruitment and re-expansion of lung tissue over a longer period at higher volumes could be a possible explanation of the significantly increased oxygenation. However, whilst this study provides evidence on the efficacy of DBEX's in terms of arterial oxygenation, it failed to look into the incidence of PPC's, although this was not the focus of the study. The authors support the implementation of a higher rate of DBEX's in the initial phase following cardiac surgery.

Incentive Spirometry (IS) is another commonly used device by physiotherapists following cardiac surgery. In an earlier paper, Crowe and Bradley (1997) explored the addition of IS to postoperative pulmonary physiotherapy is more effective that physiotherapy alone in reducing PPC's in high risk patients after CABG surgery. Patients with a chronic airflow limitation, defined as an FEV1/FVC ratio of less than 0.8 and a measured FEV1 of less than 70% of the predicted value were included in the study. Patients with haemodynamic complications or those who were intubated for longer than 72 hours were excluded. For the 185 eligible participants, subjects were randomly assigned to receive either postoperative physiotherapy which consisted of breathing exercises, secretion removal and mobility, or physiotherapy combined with IS. The primary outcome measure was atelectasis, estimated by chest radiography and was evaluated by a single observer, blinded to allocation. Secondary outcome measures included the estimation of pulmonary infection, oxygen saturations and length of stay in hospital.

The results demonstrate no significant difference between the two groups for the outcomes measured. The overall rate of pulmonary infection was 9.7%, which was greater than that found by Brasher et al (2003). The authors acknowledge several limitations. As an RCT, the control group was still receiving physiotherapy treatment, as no treatment for patients would be considered high risk and not approved by an ethical review board. This has also been commented on elsewhere by Johnson et al (1996). However, the results showed that among the 22 subjects who developed clinically important atelectasis on extubation, there was a risk reduction of 22% demonstrating a trend toward the benefit of added IS compared to physiotherapy alone. This trend however did not reach a level of statistical significance, which the authors acknowledge would have been due to the small number of subjects with marked atelectasis. This is another common feature among the evidence surrounding physiotherapy in cardiac surgery, as most results are based on relatively small numbers and a lack of statistical power.

Dias et al (2010) evaluated three physiotherapy protocols and their effects on pulmonary volumes in patients undergoing cardiac surgery. 35 patients were randomised into 3 groups; Group 1 as an exercise control group, providing mobilisation and cough procedures only; Group 2 who performed long breaths using the IS in addition to mobilisation and coughing and Group 3 who performed Breath Stacking technique (BS) including successive inspiratory efforts using a face mask coupled to a unidirectional valve together with mobilisation and coughing maneuvers. The 3 physiotherapy protocols were provided twice daily for five days, and each session consisted of 3 series of 5 maneuvers. The main outcome measure used was Forced Spirometry which was carried out preoperatively and during postoperative days 1 to 5 allowing the pulmonary volumes to be measured. All patients were eligible for inclusion if they underwent surgery during November 2007 and February 2009, however patients were excluded if they experienced haemodynamic complications, major blood loss, MI or those who were intubated for more than 72 hours after admission or the need for reintubation.

The results showed the FVC significantly decreased on postoperative day 1 for all groups, as well as the inspiratory volume in the IS and BS groups were reduced. Following this, on postoperative days 1 to 5, the FVC partially normalized for all of the groups however, for the BS group (Group 3) the inspiratory volume was found to be significantly higher compared to the IS (Group 2). The authors discuss several limitations including a common trend as identified previously containing a small study cohort and the specificity of the population, as the patients included were considered "low risk" for the development of pulmonary complications and could not be extrapolated to other populations, however this was not discussed further. The authors conclude the BS techniques promoted higher inspiratory lung volumes in this sample, which conflicts with the findings from Crowe and Bradley (1997).

Similarly, in 1994, Stiller et al, set out to investigate whether prophylactic chest physiotherapy significantly decreases the incidence of pulmonary complications after CAS (Coronary Artery Surgery). By means of a RCT, 120 patients who underwent CAS were randomly allocated into 3 groups. Group 1 patients received no preoperative or postoperative chest physiotherapy. Group 2 patients received preoperative education and instruction in breathing and coughing exercises and postoperative supervision of the exercises only and patients were seen twice/day on the first and second postoperative days, and once/day on the third and fourth postoperative days. Whilst group 3 patients received the same physiotherapy treatment except patients were seen by a physiotherapist four times a day on the first and second postoperative days, and twice/day on the third and fourth postoperative days. Patients were excluded from the study if they were intubated and ventilated for greater than 24 hours or developed neurological complications.

The results shown there to be an incidence of clinically significant postoperative pulmonary complications of 7.5%, higher than that found by Brasher et al (2003) and less than the 9.7% reported by Crowe and Bradley (1997). There was no significant differences between the groups in the patient's preoperative profiles or pulmonary function test results. Similarly, operative and postoperative details for the groups did not differ. As found previously, there were insufficient numbers in some of the categories to generate statistical analysis and determine effect.

Although of the 7.5% (n=9) that developed clinically significant PPC's, their LOS was significantly prolonged ($p=0.002$), which is in agreement with the findings from Brasher et al (2003). Furthermore, the authors allude to an association to the development of PPC's and Left Ventricular Failure (LVF), as 5 of the 9 patients who developed PPC's also had LVF. Additionally, despite the preoperative characteristics of the study cohort were collected, they did not appear to identify patients at higher risk for the development of PPC's. Interestingly, with those patients who developed PPC's, 3 patients developed pulmonary complications within 12 hours of their surgery. Although it can be argued that as this occurred prior to the time that chest physiotherapy treatment were due to take place and therefore could not be attributable to the presence or absence of physiotherapy (Stiller et al, 1994). One question that has emerged, is the timing of the provision of chest physiotherapy optimal? If physiotherapy strategies were commenced earlier following cardiac surgery, would this have altered the outcome? Subsequently, this remains uncertain.

In response to the challenge of traditional physiotherapy regimes and the strive towards fulfilling early extubation protocols, rapid recovery guidelines and maximising a patients respiratory potential, when considering early intervention strategies, it is paramount to consider its influence on clinical outcome. To date, the vast majority of research with regards to physiotherapy after cardiac surgery is post extubation. Subsequently, there are limited studies into the effectiveness of chest physiotherapy treatment of mechanically ventilated patients thereafter, which has been investigated by Eales et al (1995). The authors postulate that too much time is spent on times of routine treatment and how other regimes are often overlooked (Eales et al, 1995).

The aim of this research was to evaluate the effects of a single chest physiotherapy treatment to 37 postoperative mechanically ventilated cardiac surgery patients. Additionally the study set out to determine which of the physiotherapy techniques were most effective. These patients had a median sternotomy, undergone extracorporeal bypass intra-operatively, and had coronary artery bypass or valvular surgery and were allocated, at random to one of three groups. Group 1 (n=11) were suctioned after a 3-minute pre-oxygenation via the ventilator; Group 2 (n=15) received in addition 6 manual hyperinflation breaths prior to suctioning; Group 3 (n=11) were treated as group 2, although received chest wall vibrations during the expiratory phase of the manual hyperinflations. Patients were excluded from the study if they were haemodynamically unstable, or were likely to require intubation for greater than 18 hours. The treatments were commenced approximately 18 hours after the cessation of anaesthesia and return to the ICU. The outcome measures used were a calculated Effective Dynamic Compliance (EDC) and Arterial Blood Gas analysis (ABG) taken pre-treatment, 3 minutes after the pre-oxygenation, then at 10, 30 and 60 minute intervals following treatment. Their results demonstrated no significant differences in EDC or ABG valves between the three groups. Moreover, the authors failed to interpret any changes in physiological parameters in relation to clinical outcome. On further analysis, the treatments were undertaken approximately 18 hours following the cessation of anaesthesia, a timeframe which does not appear to be in conjunction with current clinical practice, and local protocols championing a culture of early extubation. Furthermore, in acknowledgement that patients with a pre-existing pulmonary dysfunction are at greater risk of PPC's, they failed however to provide such vital information with relation to the preoperative characteristics of their small cohort of subjects. In addition, their findings were representative of uncomplicated mechanically ventilated patients following cardiac surgery, however those patients who were likely to require intubation for greater than 18 hours were excluded. This exclusion criteria appears peculiar and lacks clarification. Subsequently, whilst this study provides evidence on the effects of chest physiotherapy in mechanically ventilated patients following cardiac surgery, with recognising the issues with the methodology, together with the obscure timeframe of treatment, makes it difficult to consider the findings as a representative of the cardiac surgical population.

More recently, a randomised control trial was undertaken by Patman et al (2001) with their physiotherapy practice sharing a common interest to adhere to early extubation protocols. The question as to whether or not physiotherapy treatment following cardiac surgery is necessary during the intubation period was investigated. 236 patients following elective or semi-urgent cardiac surgery were randomly allocated into 2 groups, to receive physiotherapy interventions during the period of mechanical ventilation (treatment group) or to receive physiotherapy treatment only following extubation (control group). The dependent variables were length of intubation period; length of ICU stay; length of hospital stay and the incidence of PPC's. Physiotherapy treatment were not standardised as during the assessment of each subject, a different intervention may be required. The physiotherapy techniques used were those commonly used when a patient is intubated, including positioning, manual hyperinflation and endotracheal suctioning. The results of this study demonstrated no significant difference between the two groups, suggesting that the provision of physiotherapy treatment during the initial period of mechanical ventilation does not enhance the desired outcomes. Additionally, in relation to the exclusion criteria it seems obscure that any subject with a past medical history of asthma, chronic airflow limitation and bronchiectasis, were excluded from the study. It was felt that these conditions may have influenced the provision of the physiotherapy intervention, however the influence of a substantial impairment in respiratory function on the development of PPC's has been consistently documented (Kroenke et al 1993; Cohen et al, 1995; Michalopolous et al, 2001). Consequently, it seems relevant to question if patients with a preoperative diagnosed respiratory impairment, particularly those diagnosed as severe COPD, with an FEV1 of less than 50%, thought to be at higher risk of more serious pulmonary complications (Kroenke et al, 1993) had been included, whether or not the desired outcome measures would have improved.

Likewise, the subjects included in the current study were following uncomplicated coronary artery surgery, thus who underwent their surgery either on an elective or semi-urgent basis. It is noted by the authors that patients requiring urgent or emergency surgery were excluded, yet it is those patients who are proposed to encounter a respiratory and cardiovascular instability to a greater extent during the peri-operative period (Patman et al, 2001). This then poses a clinical question, would those patients respond differently to physiotherapy interventions during the crucial intubation period postoperatively?

Additionally, a common exclusion criteria among physiotherapy RCTs, all subjects requiring more than 24 hours of mechanical ventilation were not considered as routine, and were withdrawn from the study. Although as acknowledged by the authors, little information is known regarding the characteristics of the subjects that required prolonged ventilation in this study.

To date, although there is scarce evidence into the effects of physiotherapy treatments during the intubation period following cardiac surgery, the study by Eales et al (1995) and Patman et al (2001) deduce how prophylactic physiotherapy treatment does not influence clinical outcome. However, the weighted argument can only be considered representative of a routine, uncomplicated pathway of care. Hence, it can be argued that other sub-groups of the cardiac surgical population may respond differently to physiotherapy during this time.

Hence, a generalised early intervention physiotherapy treatment programme delivered to all patients immediately following cardiac surgery appears superfluous, as without interventions to effect the desired outcomes, merely supplementary costs are incurred. The research carried out to date implies an early intervention programme be best targeted to certain sub-sections of the cardiac surgical population thought to be at risk of developing PPC's following surgery, although these studies would infrequently explore the study cohorts to identify those at greater risk. Therefore, if those individuals at high risk for the development of PPC's could be identified, future research into early intervention strategies would be worthwhile. This produces an unequivocal direction into which further investigation into the provision of physiotherapy services within cardiac surgery be focused.

The physiotherapy evidence discussed in this review suggests that historical practice is now being questioned in response to rapid recovery guidelines and that physiotherapy practice varies among centers utilising an array of techniques. However, in clinical practice, controversies exist over the treatment selection and the literature portrays an ongoing debate relating to their efficacy. Although there is evidence to show that physiotherapy techniques maybe beneficial in addressing PPC's. The literature included in this review has reported the incidence of PPC's following cardiac surgery to range from 2.6% to 9.7% and several studies have demonstrated the impact of PPC's including the demand for greater physiotherapy time and resources together with necessitating an increased length of stay in intensive care. Furthermore, a recurring issue noted when reviewing the studies was the failure to identify those patients at risk for development of PPC's based on preoperative risk factors.

Although, whilst the studies included in this review are often randomised control trials, and are considered a gold standard in terms of research method design, many of them are based upon patients undergoing specific surgery, e.g. following CAS and/or valve surgery and not the cardiac surgical population as a whole. Also, the vast majority often have small sample sizes and thus has a lack of statistical power to generate effect which fuels the debate. However, the optimal timeframe to provide physiotherapy treatments is a regular topic for discussion within the literature and having a greater understanding of the cardiac surgical population in order to predict those at greatest risk of complications will maximise the potential benefit of an early intervention programme and validate the necessary resources required.

Both of the review chapters have afforded the knowledge base, necessary to explore risk factors for the development of PPC's, together with evaluating the bearing of this complication on clinical outcomes for the service. Although this has been fundamental in the strive towards achieving the overall aim of this thesis, it is imperative to have an appreciation for other factors that could have a potential influence on PPC's following cardiac surgery. There are other surgical and psychosocial factors that have not been identified as they were beyond the scope of the literature review chapters, however, they will be discussed for their potential influence and relevance in this project within the discussion chapter (6.0).

3.6 Summary

In summary, the literature surrounding complications following cardiac surgery has confirmed the most problematic complication to be pulmonary in nature, increasing the risk of morbidity and mortality postoperatively. The influence of PPC's on clinical outcome including intensive care LOS, PMV and readmission have been emphasized, which has provided a comprehensive understanding of PPC's which was set out in the overall aim of this work. The evidence has also supported the role of physiotherapy strategies to overcome or reduce the incidence of pulmonary complications based on the identification of risk factors. This is imperative to optimize clinical outcome and performance.

The physiotherapy literature included in this review demonstrates the evidence surrounding the timing and efficacy of this service in addressing pulmonary complications, is questionable. Although there is limited information, there appears to be a central theme emerging that promotes an earlier intervention physiotherapy service to reduce PPC's and enhance clinical outcomes. Subsequently, if there is a need for a clearly defined and optimally timed physiotherapy intervention, it is vital to identify those patients that would maximally benefit from an early intervention service.

The literature centered upon preoperative characteristics and risk factors generated from the systematic review (Chapter 2.0) and the evidence surrounding the impact of PPCs on postoperative morbidity and mortality, as contained within this narrative review has provided a considerable evidence base. It is now crucial to consider its application to the local population undergoing cardiac surgery before future developments within physiotherapy can be considered. However, the local population has not yet been defined. Therefore, in order to further address the aim of this project, it is necessary to have a greater appreciation of the local cardiac surgical population, so that any proposed changes within physiotherapy practice in cardiothoracic surgery is founded upon their clinical needs. The findings of both review chapters will be utilised to inform the rationale and framework for the service evaluation of cardiac surgery (Chapter 5.0), as the preoperative characteristics and postoperative outcomes that will be extrapolated from the clinical records have now been established. Prior to this, the decision making process that facilitated the conceptual and theoretical framework for the service evaluation will now be reviewed in Chapter 4.0.

4.0 A Conceptual and Theoretical Framework to Evaluate Cardiothoracic Surgical Services at ABMU, Cardiac Centre.

4.1 Introduction

The previous chapter has discussed and critically evaluated the relevant literature on the development of PPC's following adult cardiac surgery. From this, there is a demand to describe the local cardiac surgical population to assist with addressing the aim of this project. Subsequently, the next requirement is to undertake an evaluation of the cardiothoracic surgical services at the cardiac centre, ABMU health Board.

This chapter will identify some of the research methods available to conduct an evaluation and will aim to follow phases of an evaluation as proposed by Ovretveit (1998). This will assist with planning the process of the service evaluation, as it is necessary to perform an evaluation in a systematic way, utilising a carefully phased approach, as outlined below. Additionally, the quality framework of Donabedian to define and evaluate healthcare and its application to the service evaluation of cardiothoracic services at the clinical centre will be discussed.

4.2 Initiation

In primary healthcare, research in relation to clinical effectiveness trials of treatments or services are often generated through large-scale, multicenter studies, however are associated with considerable financial requirements. However, it is plausible to undertake a local, small-scale evaluation that is produced within an existing budget (Brophy, Snooks and Griffiths, 2008).

Although the evaluation of a service is often more complex than the evaluation of a single treatment. Rather, when evaluating a service, it can involve more than one treatment, as well as the delivery of the treatment given to the patient, plus the organizational context and environment of care (Ovretveit, 1998).

According to Ovretveit (1998):

"Evaluation is attributing value to an intervention by gathering reliable and valid information about it in a systematic way, and by making comparisons for the purpose of making more informed decisions or understanding causal mechanisms or general principles"

Ovretveit (1998; p.9)

It is crucial to differentiate how this differs from research and clinical audit, which are other research methods that could be employed. Research is designed to seek new knowledge that can be applied to the wider setting from which it was conducted. According to the NHS Research Ethics Centre, research attempts to determine generalizable, knowledge including studies that aim to generate hypotheses as well as studies that aim to test them. Research aims to address clearly, defined questions, aims and objectives (National Patient Safety Agency, 2009).

However, clinical audit is designed to produce information to inform the delivery of best care i.e. comparing against an evidence based standard or guideline (Brophy, Snooks and Griffiths, 2008; National Patient Safety Agency, 2009). Clinical audit aims to determine "Does this service reach a predetermined standard?" (National Patient Safety Agency, 2009).

In comparison, service evaluation is designed and conducted to define or judge current care, and aims to determine "what standard does this service achieve?" without reference to a standard (National Patient Safety Agency, 2009).

In consideration of this, a small-scale service evaluation is the most appropriate methodology to evaluate the cardiothoracic surgical services at ABMU Health Board. According to the Health Quality Improvement Partnership (HQIP, 2011), this will incorporate the development and evaluation of practice and services and will mostly rely on the use of data contained in current hospital information systems. Service evaluation in healthcare is thought to enhance the local knowledge base and improve the quality of local-decision making (HQIP, 2011).

4.3 Formulation and Proposal

Developing a clear idea of the purpose of the service evaluation is a fundamental step in ensuring a systematic process. Therefore the purpose of undertaking an evaluation at the ABMU cardiac centre is:

1. To determine how the current cardiothoracic surgical service works?
2. To understand the preoperative characteristics of the local cardiac surgical population presenting for cardiac surgery.
3. To define the current levels of surgical activity including the types of cardiac surgical procedures undertaken at the clinical centre.
4. To explore the trends relating to clinical outcomes including length of stay and incidence of postoperative complications.

4.4 Reviewing Knowledge

The literature contained within the systematic review (chapter 2.0) and in the narrative review (chapter 3.0) has provided the background evidence necessary to set the context of this service evaluation within the evidence already available within this field.

The evidence has also assisted with planning the approach to the evaluation, in determining the evaluation design, as well as the reason for undertaking the evaluation. On completion, the literature searches will also facilitate the interpretation of the evaluation findings by enabling comparisons to be made to the work of others.

Additionally, the quality of the evidence included in the review chapters needs to be considered. Much of the evidence included are based upon cross-sectional surveys, case-control studies, cohort studies, randomised-controlled trials, as well as systematic reviews, which conforms to the hierarchy of evidence quality. Furthermore, the CASP critical appraisal process, undertaken in the systematic review (chapter 2.0) has also ensured the inclusion of high quality literature.

4.5 Finalising details of design and methods

The options of designing the evaluation depend on its purpose. For example, it can be designed to determine the impact of a programme or intervention and is usually termed 'summative' or 'outcome' evaluation. Furthermore, if costs of implementing a programme or intervention need to be evaluated, then a 'cost-effectiveness' evaluation is appropriate (Brophy, Snooks and Griffiths, 2008).

The purpose of undertaking a service evaluation of cardiothoracic surgical services at the current clinical centre will be designed according to how the current programme is working. This is a method known as 'process' or 'formative' evaluation. This type of evaluation will examine how the programme or service is implemented and also how it is being delivered (Brophy, Snooks and Griffiths, 2008). However, in order to address the purpose of this evaluation, the design will have features of both process/formative evaluation and summative/outcome evaluation.

The evaluation at the cardiac centre will be carried out internally, i.e. by individuals who are part of the organisation. Although this can have the advantage that the evaluator will have detailed knowledge of the service that is being evaluated. Based on this, their commitment to implementing any recommendations is more likely, however, it is also suggested that internal evaluators may have vested interests (Palfrey, Thomas and Phillips, 2012).

Alternatively, an external evaluator could be sought with the advantage of having an independent and perhaps a more critical viewpoint. However, they may be less aware of the complexities that exist within the organisation (Palfrey, Thomas and Phillips, 2012). Furthermore, external evaluations are also more expensive (Brophy, Snooks and Griffiths, 2008).

4.5.1 Dimensions to be evaluated

A central component in planning a service evaluation is the decision on which dimensions of the service that are to be evaluated.

In order to structure this, several quality frameworks were reviewed. Smith and Cantley (1985) features 'Pluralistic' evaluation and postulates that it is unwise to rely on a single set of data, from a single source using one method of data collection, and rather they advocate to escape the traditional or 'method bound' approach and to use a richer or 'Pluralistic', more complex evaluation framework. It was put forward that the single center, small scale evaluation that is to be undertaken in this project, did not conform to this approach. Additionally, Maxwell (1984) identifies 6 criteria within a framework that focuses on social acceptability and humanity. The criteria are effectiveness, efficiency, appropriateness and relevance to need, equity and accessibility, which were beyond the scope of this project.

Subsequently, the quality framework developed by Donabedian (1988) is proposed for this evaluation. This focuses on a framework of the intuitive relationship between three concepts: 'Structure, Process, and Outcome' (McDonald, Sundaram, Bravata et al, 2007). It is suggested that all three elements are required to provide the overall picture of the service. These are illustrated in Figure 5.

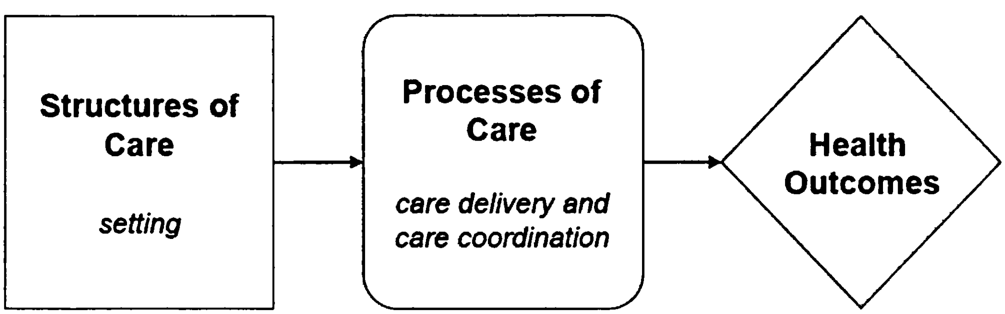

Figure 5: Donabedian's Quality Framework
(McDonald, Sundaram, Bravata et al, 2007)

By employing the Donabedian approach to defining or evaluating healthcare, the three concepts within the quality framework and the elements contained within each concept are outlined below.

'Structure' examines the provision of inputs and resources, including facilities, available staff, number of hospital beds, geographical area, and ease of access. 'Process' relates to activity levels and use of resources, for example, what is done for and to a patient or population and how well. This could include bed occupancy, referral patterns, time from diagnosis to treatment, how patients are recruited e.g. screening, and admission procedures. 'Output' relates to productivity or throughput, for example, length of hospital stay, waiting times, discharge rates, effectiveness and equity. 'Outcomes' refer to the effectiveness of activity and change in health status, i.e. mortality, morbidity, complication rate, disability and quality of life.

The concepts of the Donabedian framework are proposed to be flexible enough to apply to any clinical situation (McDonald, Sundaram, Bravata et al, 2007) and the elements that will be incorporated in the planning of this service evaluation, will now be illustrated in figure 6.

Structure	Process	Output/Outcomes
The cardiac centre provides tertiary cardiac services for a population of 933, 000 in Swansea and West Wales. 8 Intensive Care Beds 8 High Dependency Beds 25 Surgical Ward Beds 24 hour access to Cardiothoracic Surgeons, Anaesthetists, Nursing Staff, Allied Health Professionals.	Referral via G.P, Accident and Emergency, Cardiology Detailed clinical history and preoperative patient characteristics will be established including: Age Gender Past medical history History of pulmonary disease Smoking history Renal insufficiency Patients are screened for surgery using a variety of screening measures to determine: Extent of cardiovascular disease Pulmonary Function LV Function via TTE	<u>Output:</u> Number of cardiac procedures undertaken: CABG Surgery Valve Surgery Combined Surgery Thoracic Aorta Surgery Length of Stay on Intensive Care Length of Hospital Stay Time to extubation Discharge rates <u>Outcomes:</u> Mortality rate Morbidity Incidence of reintubation Incidence of readmission to intensive care Incidence of postoperative complications

Figure 6: The application of Donabedian's Framework to evaluate cardiothoracic surgical services at ABMU, cardiac centre.

The elements contained within each concept of the quality framework together with the evidence base from the literature review chapters will inform data collection for this service evaluation.

4.6 Data Collection

4.6.1 Sampling

In addition to confirming which of the desired elements for which data will be collected, the quality of the evaluation also depends on the quality of the data to be collected (Brophy, Snooks and Griffiths, 2008). A key feature of ensuring quality of data collection is ensuring that the sample is both representative and generalisable. This will provide information from this sample that could inform our understanding of the whole cardiac surgical population. In order to address this, the strategy of sampling needs to be considered.

Quota sampling or purposive sampling will be employed in this evaluation, with the aim of reproducing the proportion of groups within this population. For example, all patients undergoing cardiac surgery during a set timeframe will be included in the evaluation. However, as this method is not random sampling, it could be argued that each member of the population does not have an equal chance of inclusion.

4.6.2 Data Sources

Using a retrospective audit design, data will be extrapolated from clinical notes and existing hospital information systems. The electronic database for the patient cardiac administrative system will be used to access existing data, as well as medical notes and physiotherapy documentation. Quantitative data will then be recorded in a database format. Although this method for evaluators requires a critical eye (Palfrey, Thomas and Phillips, 2012) and is time consuming, there may also be concerns relating to the quality of the data, such as missing data, or some handwritten notes may be difficult to read. Although, it is suggested that this method permits a unique account of patient care to be obtained (Brophy, Snooks and Griffiths, 2008). However, in recognition of how the quality of data collection could be compromised, a single person will be responsible for all of the data collection, and following its completion, a random audit of the datasets will be undertaken to ensure continuity.

4.6.3 Research Governance and Ethics

Ethical approval for this service evaluation is not required as service evaluation do not warrant mandated REC (Research Ethics Committee) review. This advice has been sought via the NHS Research Ethics Centre (National Patient Safety Agency, 2009) with reference to the guidance notes for research, service evaluation and clinical audit and is available at http://www.nres.npsa.nhs.uk. Subsequent approval for this service evaluation has been obtained and registered with the local NHS Research and Development, Audit department.

4.6.4 Data Confidentiality

Ensuring data confidentiality includes the protection of patient information to avoid inappropriate disclosure and ensuring that all identifiable information is not made available to unauthorised persons. Subsequently, in order to ensure the safe protection of confidential patient data, all data will be coded and not linked to any identifiable, personal or potentially sensitive information. These measures adhere to the principles of the Caldicott report of patient information and confidentiality (Crook, 2003).

4.7 Data Analysis and Reporting

Following the data collection phase, quantitative data from the database will be collated and coded for analysis on SPSS (Software Package for the Social Sciences). The database will mainly consist of nominal and interval data. Nominal data refers to categorical discrete data that belongs to a definable category, i.e. Gender. Interval data refers to data that is measured along a scale where the intervals between each value are equally split, i.e. Age. Descriptive statistics will be also reported for all variables and the datasets will be tested for normal distribution. The outcome of this will determine whether a parametric or non-parametric test will be used for further statistical analysis. Parametric tests assume that the data is distributed normally and that the samples from different groups are independent and assumes equal variance between the groups. Non-parametric tests assume that observations from different groups are random, are mutually independent and identically distributed from their respective populations.

4.8 Summary

This chapter has presented a framework which provides both a conceptual and theoretical underpinning to the planned service evaluation. Additionally a defence of the research methodology employed has been discussed. This systematic planning to evaluation is a crucial step that has provided the context required so that the service evaluation at the local clinical centre can now be undertaken.

5.0 A Service Evaluation of Cardiothoracic Surgical Services at the Cardiac Centre, ABMU Health Board and the Impact of Postoperative Pulmonary Complications on Clinical Outcomes.

5.1 Introduction

As previously identified, the profile of the patient that is referred for cardiac surgery in the UK has altered. A Larger quantity of patients are now referred for surgery presenting with significant triple-vessel disease thus increasing the number and proportion of high risk patients undergoing surgery (Tuman et al, 1992; Ferguson et al, 2002; Hulzebos et al, 2006; Bridgewater, 2011).

In recent years the cardiac surgical patient is perceived to be older, with the mean age increasing from 65.1 years as reported by Ferguson et al, in 2002 to 66.9 years, in 2009 (Bridgewater et al, 2008). Furthermore, increasingly octogenarian patients present for cardiac surgery (Wharton and Linter, 2009) who are frailer and exhibit many co-morbidities, and some patients are undergoing cardiac surgery for the second time (Tuman et al, 1992; Zaidi et al, 1999; Ferguson et al 2002; Canver and Chanda, 2003; Hulzebos et al, 2006).

On a national level, access to cardiac surgery activity and outcomes in the U.K has been permitted via the information held in the UK National Adult Cardiac Surgery Audit (NICOR, 2011). This has provided a useful benchmark of valuable clinical information regarding performance outcomes and patient characteristics, to which comparisons of the local population can be drawn.

The age profile of patients within the national report have confirmed that surgeons are operating on progressively higher risk patients every year and that patients over the age of 75 years make up more than 20% of the total cardiac caseload, and 5% of the patients are over 80 years (Bridgewater et al, 2008). The report demonstrated the average age of patients undergoing cardiac surgery in 2007 to be 66.4years, which slightly increased to

66.9 years in 2009, with females accounting for approximately 27% of the population. (Bridgewater et al, 2008).

It appears as though, despite the increasing risk inherent within the patient profile, the mortality rates are on a downward trend, decreasing from 4.0% in 2001/2002, to 3.13% in 2007 to 2009 and remained consistent at 3.1% in 2010/2011. However, despite the reported improvements in service outcomes, patients remain at risk of adverse outcomes following surgery (NICOR, 2011).

As formerly identified, the cardiac surgical procedure is one that poses the risk of postoperative complications, and specifically the respiratory system is thought to be subjected to an array of stresses (Adair and Kon, 1994). PPC's following cardiac surgery are found to occur more frequently than cardiac complications (Michalopolous et al, 2006; Laizo et al, 2010; Rahmanian et al, 2010; Yazdanian et al, 2013). The development of PPC's in patients undergoing CPB and its impact on mortality and morbidity rates has been well documented (Ng et al, 2002; Wynne & Botti, 2004; Poelaert and Roosens, 2009). The reported incidence of PPC's following cardiac surgery is variable, from 12% to 33% in other series (Rady et al, 1997; Hulzebos et al 2003). More specifically, PPC's such as atelectasis is thought to be the most common respiratory complication and the reported incidence ranges from 65% to 90% (Wilcox et al 1988; Johnson et al, 1996; Pasquina et al 2003), and pneumonia is thought to occur in 3% to 16% of patients postoperatively (Gaynes et al, 1991; Weissman, 2000; Pasquina et al, 2003). Furthermore, the pathogenesis of pulmonary dysfunction associated with the effect of CPB on the respiratory system has been consistently documented, although this evidence remains conflicting (Weissman, 2000; Ng et al, 2002; Babik et al 2003; Wynne & Botti, 2004; Weissman et al 2004; Poelaert and Roosens, 2009).

On the other hand, various non-surgical factors may enhance the impact of a cardiac procedure on pulmonary function (Adair and Kon, 1994). Patient characteristics have been proposed to influence the development of PPC's within the literature. It is thought that this complication has been reported to be attributable to advancing age, pre-existing lung disease and impaired cardiac performance according to Poelaert and Roosens (2009). The association between cardiac dysfunction and pulmonary dysfunction after cardiac surgery has also be reported by others, with reference to low cardiac output and impaired LV function (Kollef et al, 1995; Christakis et al, 1996; Rady and Ryan, 1999; Johnson et al, 2001; Weissman, 2004),

The identification of potential factors responsible for the nature of PPC's following cardiac surgery appears complex and multi-factorial. Numerous studies that have examined the risk factors for PPC's (Christakis et al, 1996; Rady et al, 1997; Ng et al, 2002; Rodrigues et al 2002; Hulzebos et al, 2003; Wynne & Botti, 2004; Poelaert and Roosens, 2009). Pre-operative characteristics thought to predict such complications are female gender (Sawatzky and Naimark, 2009), age >70yrs (Arom et al, 1995; Christakis et al, 1996; Rady et al, 1997; Zaidi et al, 1999; Rodriguez et al, 2002; Al-Alao et al, 2012), productive cough, diabetes mellitus, a history of cigarette smoking (Christakis et al, 1996; Ngaage et al, 2002; Hulzebos et al, 2003; Ashraf et al, 2004; Al-Sarraf et al, 2008), COPD (Cohen et al, 1995; Christakis et al, 1996; Samuels et al, 1998; Smetana, 1999; Michalopolous et al, 2001; Saleh et al, 2012), and NYHA functional class IV (Engoren et al, 1999; Johnson et al, 2001) and pre-existing renal disease (Christakis et al, 1996; Anderson et al, 1997; Chonchol et al, 2007) although the evidence is conflicting.

However, there is concurrent evidence to suggest that the cardiac surgical patient is at risk from the development of pulmonary dysfunction following surgery, due to preoperative factors, intraoperative considerations including the nature of conventional cardiac surgery and postoperative factors. Subsequently, the literature consistently supports an association between cardiac surgery and the development of PPC's. When this complication occurs, it is consequently thought to account for prolonged length of stay which was reported to be more than 10 days in 64.3% of patients studied in 2002 (Welsby et al, 2002).

The literature included in the Systematic Review (Chapter 2.0) and the Narrative Review (Chapter 3.0) has yielded an extensive evidence base surrounding the nature and causal factors of postoperative complications following cardiac surgery (Laizo et al, 2010; Sheppard, 2012) including hospital acquired infections (Kollef et al, 1997; Michalopolous et al, 2006; Rahmanian et al, 2010; Lola et al, 2011) and PPC's (Gaynes et al, 1991; Spivack et al, 1996; Leal-Noval et al, 2000; Canver and Chanda, 2003; Hulzebos et al, 2003; Filsoufi et al, 2008; Topal and Eren, 2012).

Subsequently, with this evidence in mind, together with the national reports relating to clinical outcomes, there is a need to define the local cardiac surgical population and explore patient characteristics and illustrate the trends of performance outcomes. This will allow a comparison to be made with what is believed to be known anecdotally, with that which is reported within the literature and national audit reports, thus enabling a comparison of patient and performance related outcomes. This will verify if the local population is representative of the cardiac surgical population nationwide, which is essential prior to the consideration of strategies within physiotherapy in the future.

There is also a clinical need to highlight the predictive variables associated with the development of PPC's, to ensure optimal management of this complication where possible. Additionally, the literature surrounding the impact of PPC's on clinical outcomes, such as length of stay is limited. This information is vital in appreciating the bearing of PPC's on the cardiac service. Furthermore, this is paramount to inform physiotherapy practice in cardiac surgery, as this data will provide a vital point of reference when considering what physiotherapy based interventions or treatment strategies that could be applied to avert these complications.

Subsequently, this chapter will be divided into two phases to clearly address its two different aims, which are included below:

5.1.1 Phase I: Aim

The aim is to conduct a service evaluation of surgery undertaken at the cardiac centre, ABMU Health Board. By utilising the three defined concepts for evaluation, as outlined in the quality framework by Donabedian (1988) in Chapter 4.0, data will be collated on the elements of structure, process, output/outcomes, thus ensuring an overall picture of the service. This evaluation will aim to describe the local cardiac surgical population, as well as to define the level of care, with the intent of determining "what standard does this service achieve?" (National Patient Safety, 2009) and where possible compare the findings of the local population to the national audit findings. By utilising a summative evaluation method, it will aim to determine how the service is implemented and also how it is being delivered, whilst also examining the trends of clinical outcomes.

5.1.2 Phase II: Aim

The aims of phase II are to investigate the overall impact of PPC's on clinical outcomes and to examine the local patient profile to identify characteristics that potentially influence the development of PPC's.

5.2 Methods and Materials

This service evaluation is based on patient data collected over a 2-year period at a single institution.

5.2.1 Study Location and Population

A Cohort, from 2 groups that consisted of 736 consecutive adult patients (540 Males: 196 females) undergoing cardiac operations during January to June, 2007 (n=320) and January to June, 2009 (n=416) were included in this evaluation. The selection of this timeframe was pragmatic, random and was based on clinical discussions that highlighted the predominance of PPC's following cardiac surgery. The decision to repeat the service evaluation in 2007 and again in 2009 was to ensure that neither groups included a unique set of patients during the timeframes.

5.2.2 Study Design

Utilising a retrospective audit design, the clinical notes for the 736 patients were reviewed. The audit includes all patients undergoing cardiac surgery, such as coronary artery bypass grafting (CABG), valve repair or replacement, and surgery involving the aorta.

All patients had undergone a general anesthesia and the cardiac procedures were performed by the same group of cardiothoracic surgeons, anesthetists, and cared for by the same intensive care staff throughout both of the data collection periods. The surgical techniques and method of hypothermic cardiopulmonary bypass, utilising systemic cooling to 32°C for protection of cerebral and myocardial tissue during the cardiac operations, and deep hypothermic circulatory arrest to 18°C for surgery involving the thoracic aorta, did not differ to what is considered standard operative procedures. The anaesthetic techniques include total intravenous anaesthesia comprising of a continuous infusion of propofol and a short-acting opiate i.e. remifentanyl, and a single dose of short-acting muscle relaxant i.e. rocuronium. This method of anaesthesia was considered standard practice for all consultant anaesthetists involved in the cardiac surgical procedure.

5.2.3 Post-operative CITU care

Following the patient transfer to CITU, the nursing staff are consistently monitoring the patient until the patient meets the criteria of the local guidelines for extubation. The criteria is set to include: bleeding <75mls/hour, haemodynamic stability with/without inotropic support, temperature of more than 36.0°c, assisted spontaneous breathing with pressure support 15cmH$_2$0, inspired fraction of oxygen of 40%, positive end expiratory pressure of 5cmh20, a respiratory rate of less than 30 breaths/minute, a partial pressure of oxygen in arterial blood of ≥8 kPa, a pH within normal range and no neurological deficit.

5.2.4 Exclusion criteria

As the audit cohort was obtained via purposive sampling and all consecutive patients during the identified timeframe were included and there was no exclusion criterion.

5.2.5 Ethics and Consent

The collection of this data, had no interference on the treatment of the patients at that time, therefore, it was not deemed necessary to obtain informed consent. Ethical approval for this service evaluation was not required *(National Patient Safety Agency, 2009*). However, this service evaluation was registered with the local NHS Research and Development, Audit department. To secure data confidentiality, all patient data was coded and not linked to the patients NHS number, to ensure complete anonymity.

5.2.6 Variable Selection:

Donabedian's system-process-outcome model, as outlined in Chapter 4.5.1 was employed as the theoretical and conceptual basis for this evaluation, together with the variables generated from the literature in the systematic review (Chapter 2.0) and the narrative review (Chapter 3.0). This determined which variables would be extrapolated from the clinical records. Subsequently, for each patient included, pre-operative characteristics and demographics, operative procedure and early postoperative outcomes were recorded in a computerised database format. Data was obtained from the cardiac patient administration system and patient medial notes.

5.2.7 Pre-operative variables

Pre-operative variables collected were age, gender, history of pulmonary disease, preoperative treatment for diagnosed pulmonary impairment e.g. bronchodilator therapy, smoking status, history of renal impairment, pulmonary function tests, and the assessment of left ventricular function. In relation to past medical history, the number of organ systems affected simultaneously by chronic comorbidities was identified, as shown in Table 12.

5.2.8 Operative Data

The proportions of cardiac surgical operations included in this evaluation are shown in Table 13.

5.2.9 Post-operative variables

Postoperative outcome variables calculated were the duration of postoperative mechanical ventilation i.e. hours to extubation, number of days on CITU, total postoperative stay i.e. number of days on CITU and CHDU, the incidence of the development of postoperative complications and the incidence of re-intubation, readmission to ITU/HDU, mortality rate and the overall hospital stay, in days, was recorded, as shown in Table 14.

5.2.10 Data collection

The data collection was undertaken by a Senior Cardiothoracic Physiotherapist. For each of the 736 patients included in the study, a comprehensive database or profile was developed consisting of all pre-operative variables identified, operative data, and early postoperative outcomes. Thus, allowing an analysis of their profiles to be made, determining the key characteristics of this population and an evaluation of the trends displayed within the timeframe. On completion, a random audit was undertaken to ensure continuity and completeness of data.

5.2.11 Statistical Analysis

Statistical Analysis was performed using SPSS, version 16.0. Firstly, the datasets were tested for normal distribution using the Kolmogorov-Smirnov test of normality as shown below:

Table 10: Group 1 (2007) – Tests of Normality

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	Df	Sig.
Age	.087	301	.000	.967	301	.000
Time on ITU	.375	301	.000	.403	301	.000
Days on ITU	.422	301	.000	.168	301	.000
Post op stay	.306	301	.000	.405	301	.000
Total Stay	.244	301	.000	.656	301	.000

a. Lilliefors Significance Correction

Table 11: Group 2 (2009) – Tests of Normality

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	Df	Sig.
Age	.080	413	.000	.965	413	.000
Time on ITU (Hrs)	.350	413	.000	.521	413	.000
Days on ITU	.410	413	.000	.182	413	.000
Post op stay (days)	.375	413	.000	.233	413	.000
Total Stay	.291	413	.000	.401	413	.000

a. Lilliefors Significance Correction

The results of the tests of normality for both datasets show the results to significantly differ from the normal population, and are therefore not normally distributed. Based on this information, the non-parametric Chi-Squared statistical test will be used for nominal data, and the Mann-Whitney U-test is the appropriate analysis to use for interval data. Summary descriptive statistics were computed for all variables. Continuous variables are expressed as means ± SD A p value of <0.05 was considered statistically significant and the confidence intervals were calculated.

5.3 Phase *I* Results

A total of seven hundred and thirty six consecutive patients that underwent adult cardiac surgery during Jan to June 2007 (n=320) and Jan to June 2009 (n=416) were included in this service evaluation. The percentage expressed within the results is a valid percentage, and thus excludes any missing data. The baseline characteristics of the cohort are summarised in table 12, and where possible comparisons have been made to the national audit data.

Table 12 Service Evaluation: Baseline Characteristics of the Cohort

	Group 1 2007 (n=320)		Group 2 2009 (n=416)		P Value
	N (%)	Mean +S.D	N (%)	Mean +S.D	
Sex					
Male	234 (73.1)		306 (73.6)		**0.002**
Female	86 (26.9)		110 (26.4)		0.86
Age		68.8 + 10.483		67.61+10.510	0.07
≤70 yrs	158 (49.4)		234 (56.3)		**0.00**
>70 yrs	162 (50.6)		182 (43.7)		0.281
≥80 yrs	45 (14.1)		40 (9.6)		0.588
History of Pulmonary Disease					
N/A	239 (76.8)		350 (84.1)		**0.000**
Asthma	25 (8.0)		26 (6.3)		0.889
COPD	30 (9.7)		35 (8.4)		0.535
Other	17 (5.5)		5 (1.2)		0.11
Treatment of Pulmonary Disease					
On Medication	22 (7.1)		49 (11.8)		**0.01**
No Treatment	43 (13.8)		13 (3.1)		**0.000**
N/A	246 (79.1)		354 (85.1)		**0.000**
LFT's					
Tested	19 (6.0)		40 (9.6)		**0.006**
Not Tested	298 (94.0)		376 (90.4)		**0.003**
LV Function					
Good	168 (54.5)		240 (57.7)		**0.000**
Moderate	100 (32.5)		123 (29.6)		0.124
Poor	40 (13.0)		53 (12.7)		0.178
Smoking History					
Current Smokers	40 (12.9)		45 (10.8)		0.588
Non-Smokers	104 (33.4)		152 (36.5)		0.003
Ex ≤ 1 month	4 (1.3)		1 (0.2)		0.180
Ex > 1 month to ≤ 1 year	17 (5.5)		30 (7.2)		0.58
Ex >1 year to ≤ 5 years	57 (18.3)		34 (8.2)		0.16
Ex > 5 to >20 yrs +	89 (28.6)		154 (37.1)		**0.000**
Renal Insufficiency					
N/A	305 (98.1)		388 (93.3)		**0.02**
Known Renal Failure	3 (1.0)		18 (4.3)		**0.01**

(ARF or CRF)			
Renal Impairment	2 (0.6)	9 (2.2)	0.35
Other	1 (0.3)	1 (0.2)	1.000
Past Medical History			
Nil	10 (3.2)	14 (3.4)	0.414
1 system dysfunction	43 (13.9)	74 (17.8)	**0.004**
2 systems dysfunction	105 (33.9)	128 (30.8)	0.132
3 systems dysfunction	100 (32.2)	130 (31.2)	0.048
>4 systems dysfunction	52 (16.8)	70 (16.8)	0.103

5.3.1 Patient Profile Characteristics

The cohort was predominantly male (74%) with an age range from 25 to 94 years, with a mean age of 68.14 +10.508SD. The two groups display comparable gender proportions regarding male: female ratios over the two timeframes, which are also equivalent to the national average.

Figure 7 displays a comparison in gender profiles of the current population to that reported nationally.

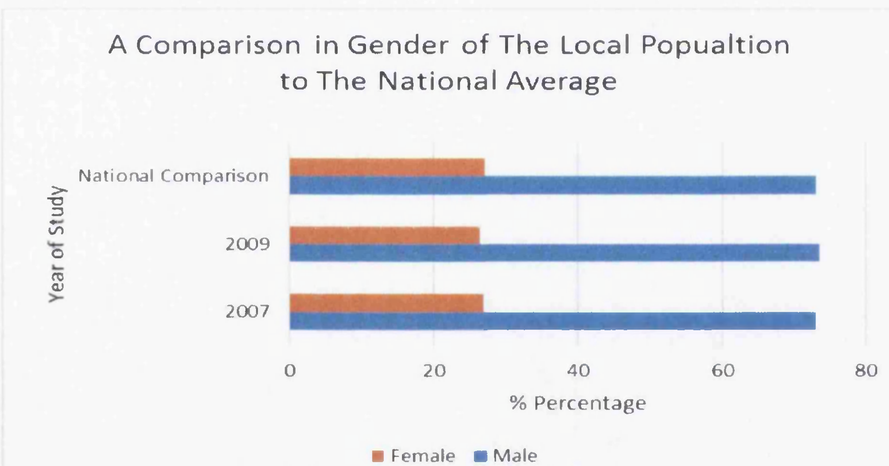

Figure 7: A Comparison in Gender Proportions of the Local Population to the National Average undergoing Cardiac Surgery

Overall, the two groups display comparable age profiles with an overall 46.4% of patients that are >70 years of age, and 11.8% of patients are octogenarian. More specifically, the mean age of patients having cardiac surgery in 2007 was 68.8 years +10.483SD and 67.61 years+10.510SD in 2009, which are higher than the national mean age of 66.4 years and 66.9 years, in 2007 and 2009 respectively.

Figure 8, as shown, below demonstrates a comparison in the mean age of the local population to the national average of patients undergoing cardiac surgery during the same timeframe.

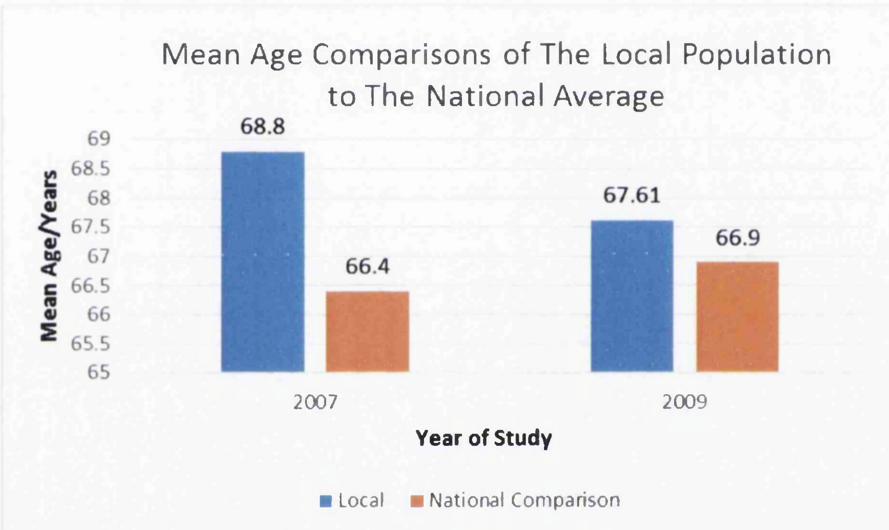

Figure 8: A Comparison of the Mean Age of Patients Undergoing Cardiac Surgery in the Local Setting to the National Average Age.

With respect to the history of pulmonary disease, the proportions are much the same within the two timeframes. However, those with a history of pre-existing pulmonary disease on medication significantly increased from 7.1% in 2007 to 11.8% in 2009 (p=0.01), thus reducing the amount of patients that present for cardiac surgery with a known pulmonary disease that are not receiving treatment from 13.8% to 3.1% respectively (p=0.000). Similarly in 2007, preoperative spirometric parameters were tested in only 6.0% of patients which increased significantly to 9.6% in 2009 (p=0.006).

In relation to left ventricular function (LV), the proportions of 'Good'; 'Moderate' and 'Poor' LV classification did not differ greatly over the two timeframes, although there were significantly more patients with Good LV function requiring surgery in 2009. There were approximate equal numbers for 'Good' LV function accounting for on average 56% of the population, and 31% having 'moderate' LV function, and 13% of patients undergoing surgery with 'Poor' LV function.

Although the vast majority of patients have no history of renal failure, the results depict the surgical population in 2007 with a pre-existing renal failure to be 1.0%, however this has significantly increased to 4.3% in 2009 (p=0.01), demonstrating more patients to be undergoing cardiac surgery with known renal disease.

The majority of the sample cohort were non-smokers accounting for 35% of the patients included which significantly increased from 2007 to 2009 (p=0.003) and on average 10% were still smoking at the time of surgery, with only slight variations over the timeframes amongst 'ex-smoker' parameters studied but of no statistical significance.

In relation to past medical history, a single system of co-morbidity was found to be present in 13.9% of patients in 2007, which significantly increased to 17.8% in 2009 (p=0.004). Otherwise, most patients presented with either 2 or 3 systems of dysfunction and over 16% of patients exhibited co-morbidities that included greater than 4 systems. This, however was comparable for the 2 timeframes evaluated and failed to reach a level of significance.

Table 13 illustrates a summary of the proportions of cardiac surgical procedures undertaken during the service evaluation period.

Table 13: Type of Surgery

	Group 1 2007 (n=320)	Group 2 2009 (n=416)	P Value
	N (%)	N (%)	
CABG surgery	198 (63.9)	232 (55.8)	0.101
Valve surgery	49 (15.8)	83 (20.0)	**0.03**
Combined CABG & Valve surgery	56 (18.1)	81 (19.5)	0.33
Thoracic Aorta surgery	5 (1.6)	12 (2.8)	0.90
Other	2 (0.6)	8 (1.9)	0.58

The results demonstrate a 30% increase in the level of surgical activity in the number of surgical procedures undertaken in 2009 in comparison to 2007, with a slightly greater proportion of isolated valve procedures, which significantly increased from 15.8% in 2007 to 20.0% in 2009 (p=0.03). Furthermore, the number of complex surgical procedures i.e. combined coronary artery by-pass and valve surgery and surgery involving the thoracic aorta were undertaken in 2009 (as indicated in Table 13), although this was not statistically significant.

The postoperative data is summarised in table 14.

Table 14:Post-Operative Data

	Group 1 2007 (n=320)	Group 2 2009 (n=416)	P Value
	N (%) Mean +S.D	N (%) Mean +S.D	
Hours to Extubation			
3-6 hrs.	44 (14.8)	164 (39.9)	**0.000**
7-12 hrs.	215 (72.1)	162 (39.5)	0.06
>12 to ≤24 hrs.	25 (8.4)	70 (17.0)	**0.000**
>24 to ≤ 48 hrs.	9 (3.0)	7 (1.7)	0.617
> 48 hours	5 (1.7)	8 (2.0)	0.405
Time on CITU			
6- ≤12 hrs.	12 (4.0)	9 (2.2)	0.513
>12 -≤24hrs	217 (71.9)	277 (66.9)	0.07
>24 -≤48 hrs.	47 (15.6)	69 (16.7)	0.41
>48 - ≤72 hrs.	12 (4.0)	12 (2.8)	1.000
96 - ≤ 120 hrs.	4 (1.3)	19 (4.6)	**0.02**
>120 hrs.	10 (3.2)	28 (6.8)	**0.04**

Post-Operative Complications			
Uneventful Recovery	185 (55.9)	227 (54.7)	0.39
Respiratory dysfunction	75 (24.3)	91 (21.9)	0.214
Neurological dysfunction	6 (1.9)	8 (1.9)	0.593
Cardiac dysfunction	42 (13.6)	104 (21.2)	0.000
Renal dysfunction	10 (3.2)	27 (5.6)	**0.05**
Other complication	15 (4.9)	33 (7.9)	0.09
Re-Intubation – Yes	8 (2.6)	17 (4.1)	0.72
Tracheostomy	6 (1.9)	10 (2.4)	0.317
Re-Admission – Yes	8 (2.6)	4 (1.0)	0.248
RIP **Survival Rate**	4 (1.3) **98.7%**	10 (2.4) **97.6%**	0.109
Days on CITU	1.18 + 5.130	2.05 + 9.059	**0.05**
Post-op stay (CITU/CHDU)	9.96 + 16.611	4.69 + 9.453	**0.000**
Total Length of Hospital Stay	15.94 + 19.204	9.25 + 10.095	**0.000**

5.3.2 Early Postoperative Variables: Length of Stay

The mean length of stay in the CITU was significantly longer for those in the 2009 group (mean 2.05 + SD9.059) compared with those whom had their surgery in 2007 (mean 1.1.8 + SD5.130; p=0.05). The length of stay on CITU was prolonged for some patients, exceeding 96 hours in 2007 (1.3%) which significantly increased to 4.6% in 2009, (p=0.02). Similarly, 3.2% of patients required a prolonged CITU stay in 2007 which increased to 6.8% in 2009 (p=0.04). Although patients in the 2009 group did spend longer in CITU, the overall stay in ITU and HDU was significantly less (mean 4.69 +9.453) when compared to a mean stay of 9.96 (SD+ 16.611) evident in 2007 (p= 0.000), as shown below in figure 9.

Figure 9 depicts the Mean LOS across the various clinical areas and the overall hospital stay.

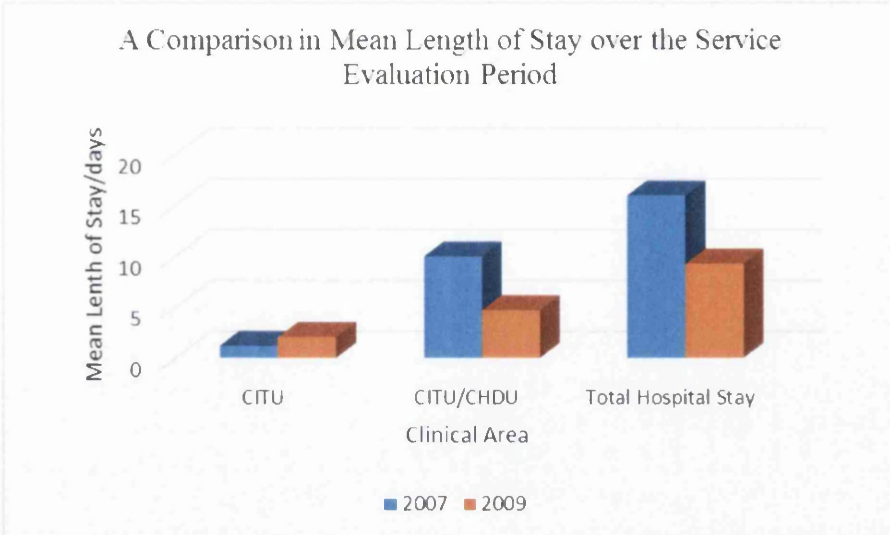

Figure 9: A Comparison in Mean LOS across the Clinical Areas during the Service Evaluation.

5.3.3 Duration of Mechanical Ventilation

Following their surgery, 72.1% (n=215) of patients in 2007 were extubated within 7 to 12 hours postoperatively, compared to 39.5% (n=162) in the 2009 group. Although in 2009, a greater number of patients, 39.9% (n=164) were extubated sooner, i.e. within 3 to 6 hours following their surgery; in comparison to 14.8 % (n=44) in 2007, which is statistically significant (p=0.000).

However, although patients were extubated within a shorter period of time in 2009, the incidence of reintubation was greater; 4.1% (n=17) vs. 2.6% (n=8). Additionally, those patients who remained intubated and ventilation for >48hours, and thus required prolonged mechanical ventilation following their surgery increased from 1.7% (n=5) in 2007 to 2.0% (n=8) in 2009. However, the differences for both reintubation and PMV between the two timeframes failed to reach a level of statistical significance.

Figure 10 illustrates the incidence of prolonged mechanical ventilation and reintubation that occurred during the evaluation timeframes.

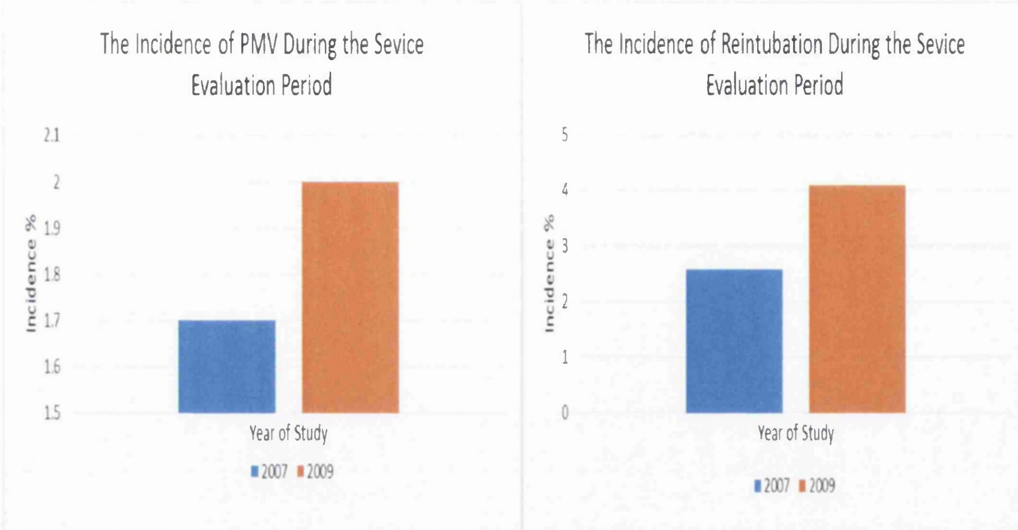

Figure 10: The Incidence of PMV and Reintubation that occurred during the service evaluation period.

Although, the incidence of readmission to CITU reduced over the service evaluation period from 2.6% to 1.0% (p=0.248) and is displayed in Figure 11.

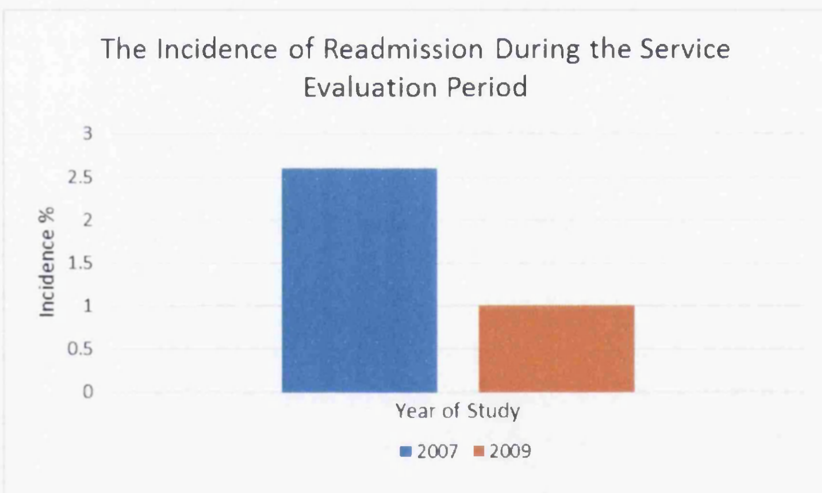

Figure 11: The Incidence of Readmission to CITU during the Service Evaluation Period

5.3.4 Incidence of Post-Operative Complications

In 2007, 55.9% of patients (n=185) had an uneventful recovery which slightly reduced to 54.7% (n=227) in 2009. Although the percentage of patients that proceeded through their surgery without complication reduced over the service evaluation timeframe, in real terms, it is important to acknowledge that the actual number of patients increased from 185 in 2007 to 227 patients in 2009. However, in relation to the development of postoperative complications, the results showed the most frequently occurring were pulmonary and cardiac in origin.

With respect to postoperative pulmonary complications e.g. atelectasis, pneumonia/consolidation, chest infection etc., the results demonstrated a similarity between the groups from 24.3% of patients (n=75) in 2007 and 21.9% of patients (n=91) in 2009 and was not statistically significant. 42 patients (13.6%) who underwent their surgery in 2007 suffered cardiac dysfunction, which developed as a complication of their original surgery e.g. excessive bleeding, arrhythmias, weaning from IABP, wound problems, PPM etc., which significantly increased to 104 patients (21.2%) in 2009 ($p=0.000$). Similarly, patients who developed renal dysfunction postoperatively increased from 3.2% (n=10) in 2007 to 5.6% (n=27) in 2009, which was statistically significant ($p=0.05$). Neurological dysfunction remained the same, occurring on average in 1.9% of patients.

The incidence of postoperative complications are illustrated in Figure 12.

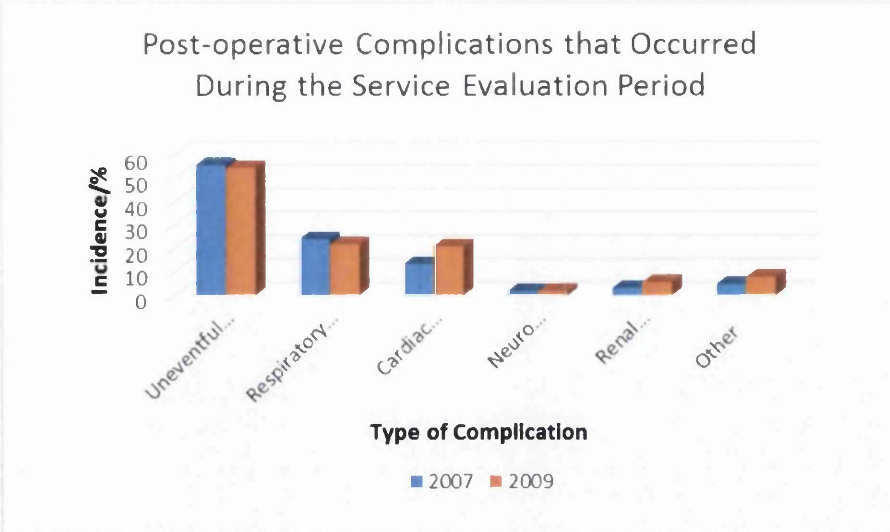

Figure 12: The Incidence of Post-operative Complications that Occurred During the Service Evaluation Period.

5.3.5 Mortality Rate

In 2007, of the 320 patients who underwent surgery, 1.3% of patients died (n=4), compared to 2.4% (n=10) of the 416 patients operated, who died following their surgery in 2009 ($p=0.109$), which is below the 3.13% national mortality rate. Figure 13, as shown below, displays the comparison in mortality rate between the local population to the national average mortality rates.

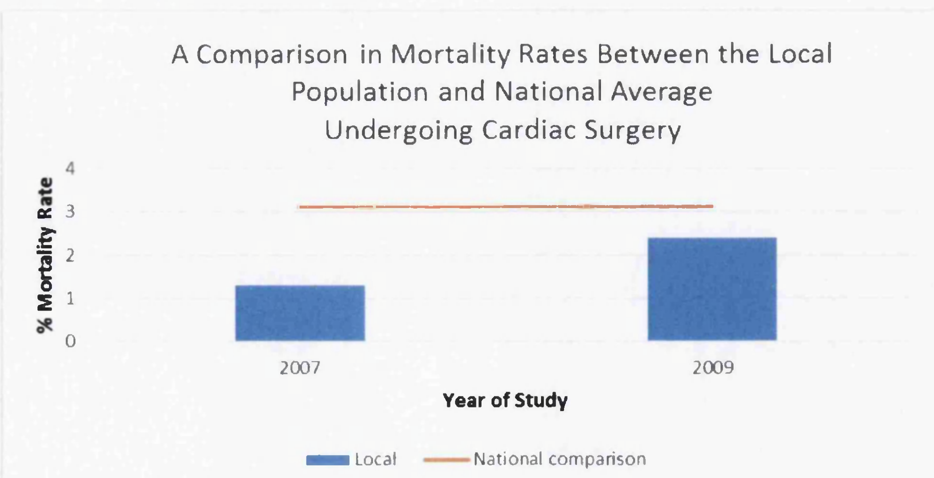

Figure 13: A Comparison in Mortality Rates Following Cardiac Surgery Locally to the National Average

5.4 Phase II Results

The results of Phase I demonstrated that there were only slight differences between the 2 year cohorts, therefore for the purpose of this phase II, the 2 groups have been combined for data interpretation. The % expressed within the results is valid percentages, and thus excludes missing data. Table 15 displays patient demographics and baseline characteristics of the combined dataset.

Table 15: Baseline Characteristics of the Study Cohort

	Patient Characteristics (n=736)
	N (%) Mean +S.D
Gender	
Male	540 (73.4)
Female	196 (26.6)
Age	68.14 +10.508
≤ 70 yrs	392 (53.3)
> 70 yrs	344 (46.7)
Age >80 yrs	
≥ 80 yrs	85 (11.5)
History of Pulmonary Disease	
N/A	589 (81.0)
Asthma	51 (7.0)
COPD	65 (9.0)
Other	22 (3.0)
Treatment of Pulmonary Disease	
On Medication	71 (9.8)
No Treatment	56 (7.7)
N/A	600 (82.5)
PFT's	
Tested	59 (8.0)
Not Tested	674 (92.0)
LV Function	
Good (EF >50%)	408 (56.4)
Moderate (EF 30-50%)	223 (30.8)
Poor (EF<30%)	93 (12.8)
Past Medical History	
Nil	24 (3.3)
One system dysfunction	117 (16.1)
Two system dysfunction	233 (32.1)

Three system dysfunction	230 (31.7)
> 4 system dysfunction	122 (16.8)
Smoking History	
Current Smokers	85 (11.7)
Non-Smokers	256 (35.2)
Ex ≤ 1 month	5 (0.7)
Ex > 1 month to ≤ 1 year	47 (6.5)
Ex >1 year to ≤ 5 years	91 (12.5)
Ex > 5 to >20 yrs +	243 (33.4)
Renal Insufficiency	
N/A	693 (95.3)
Known Renal Failure (ARF/CRF)	21 (2.9)
Renal Impairment	11 (1.5)
Other	2 (0.3)
Type of Surgery	
CABG surgery	430 (59.2)
Valve surgery	132 (18.2)
Combined CABG & Valve surgery	137 (18.9)
Thoracic Aorta surgery	17 (2.3)
Other	10 (1.4)

5.4.1 Incidence of PPC's

The results showed that 50.0 % (n=412) of patients had an uneventful recovery following their cardiac surgery and 20.2% (n=166) of the study population developed PPC's. The postoperative data is summarised in table 16.

Table 16: Post-Operative Data

	Post-Operative Data (n=736)
	N (%) Mean +S.D
Hours to Extubation	
3-6 hrs.	208 (29.3)
7-12 hrs.	377 (53.2)
13- ≤ 24 hrs.	95 (13.4)
>24 to ≤ 48 hrs.	16 (2.3)
> 48 hours	13 (1.8)
Time on CITU	
6- ≤ 12 hrs.	21 (2.9)
>12 -≤ 24hrs	494 (69.0)
>24 -≤ 48 hrs.	116 (16.2)
>48 - ≤ 72 hrs.	24 (3.4)

96 - ≤ 120 hrs.	23 (3.2)
>120 hrs.	38 (5.3)
Post-Operative Complications	
Uneventful Recovery	412 (50.0)
Pulmonary Complication	166 (20.2)
Other complication	245 (29.8)
Length of Stay CITU	1.68 days +7.667 SD
Post-Operative Stay (CITU/CHDU)	6.95 days + 13.269SD
Total Length of Stay	12.12 days +15.067SD

5.4.2 Clinical Outcomes: Length of Stay

Overall, the mean length of stay in the CITU was 1.68 days (+7.667 SD). However, the results show 11.9% (n=85) of patients whose length of stay on CITU exceeded 48 hours. The mean postoperative stay was 6.95 days (+13.269 SD) and the overall mean length of stay was 12.12 days (+15.067 SD).

Following their surgery, the majority of patients (53.2%, n=377) were extubated within 7 to 12 hours, and for 29.3% (n=208) of patients this timeframe is reduced to 3 to 6 hours postoperatively. However, 1.8% (n=13) of patients required a period of prolonged mechanical ventilation (PMV) i.e. >48 hours.

In order to address the aim of Phase II, Table 17 illustrates the comparison in clinical outcomes between patients with and without PPC's. A statistically significant difference was identified for the following variables; Days on ITU (p=0.000; 95% CI: 2.62-7.51), Mean Post-Op Stay (p=0.000; 95% CI: 8.46 -13.73) and Total Stay (p=0.000; 95% CI: 13.21-18.82) demonstrating that patients with PPC's had a longer ITU and hospital length of stay.

Table 17: A Comparison of Clinical Outcomes for those patients who developed PPC's and those who had an uneventful recovery.

Outcome	No PPC's	PPC's	P Value (95% Confidence Interval)
Mean Stay on ITU (Days)	0.4 days	5.04 Days	**0.000**; 95% CI:2.62-7.51
Mean Post-Op Stay (days)	4.5 days	13.49 days	**0.000**; 95% CI:8.46 -13.73
Total Stay (days)	8.94 days	18.6 Days	**0.000**; 95% CI:13.21-18.82

Additionally, Table 18 compares the most commonly occurring patient characteristics that exists between the two groups and identifies that LV function is the single isolated pre-operative characteristic to differ between those patient who developed PPC's and those who did not.

Table 18: A Comparison of Patient Profile Characteristics for those patients who developed PPC's and those who had an uneventful recovery.

Variable	No PPC's	PPC's
Gender	Male	Male
Mean Age	67.14	69.3 yrs
Age Parameters	<70 yrs	<70 yrs
Hx of Pulmonary Disease	No History	No History
PFT's	Not Tested	Not Tested
Type of Surgery	CABG Surgery	CABG Surgery
LV Function	Good	Moderate
Smoking History	Non-smoker	Non-smoker
Renal History	No history	No history
PMH	2 system dysfunction	2 system dysfunction

Figure 14 illustrates the impact of the development of Post-operative Pulmonary Complications on clinical outcomes.

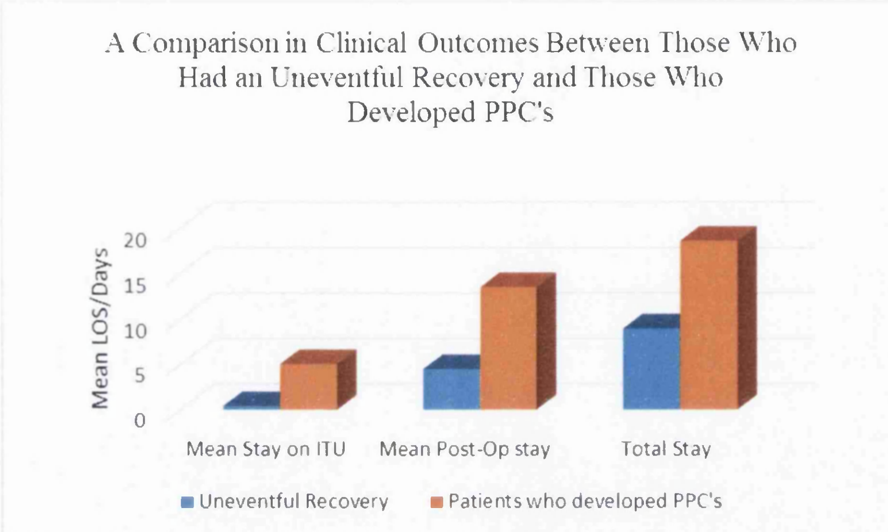

Figure 14: A comparison in clinical outcomes between those who had an uneventful recovery and those who developed PPC's

5.5 Discussion

Phase I of this chapter has defined the current level of care by obtaining a greater understanding of the local cardiac surgical population and has investigated the patient characteristics and explored the trends relating to patient and performance outcomes.

5.5.1 Principal findings: Patient Profile

A statistically significant increase in the amount of male patients presented for surgery in 2009 (p=0.002). It has been suggested that the relative amount of females undergoing coronary artery bypass surgery has risen from 25.7% in 1990, to 28.7% in 1999 (Ferguson et al, 2002). Furthermore, the national audit reported that females account for 27% of the population, and in the current study which included 26.9% of female patients in 2007 and 26.4% in 2009, appears to confirm this proportion. Female gender is a consistent feature within the risk stratification models associated with operative mortality risk (Parsonnet et al, 1989; Nashef et al, 1999; Kacila et al, 2010) and furthermore has been correlated with a greater risk for the development of PPC's and prolonged LOS in the literature (Sawatzky and Naimark, 2009).

The mean age of patients undergoing surgery in 2007 was 68.8 years and 67.6 years in 2009, which is older than 65.1 years, reported in previous investigations into the change of the cardiac patient profile over the years (Ferguson et al, 2002) and older than the national average of 66.4 years in 2007 and 66.9 years in 2009. Previous literature reports of cardiac surgery being undertaken on patients over 80 years old range from 2.6% to 5.2% (Zaidi et al, 1996; Wharton and Linter, 2009), however, of this study cohort, 11.8% of patients were octogenarian. This confirms this notion that a greater number of patients being accepted for cardiac surgery are indeed older.

Although it is felt that elderly patients have the highest prevalence of cardiac disease (Zaidi et al, 1996) and are more likely to have other pre-existing conditions (Wharton and Linter, 2009), the risk of early mortality and major morbidity is considered low (Zaidi et al, 1996, Faggian et al, 2011) and thus a plausible explanation for the increased referral of elderly patients today. However, contrary to other studies, the literature has suggested that co-morbidity and complications increase with age (Rodriguez et al, 2002; Al-Alao et al, 2012) and that patients with advanced age, i.e. >70 years, are at greater risk of extubation failure (Rady and Ryan, 1999), the early onset of severe pulmonary dysfunction after surgery (Arom et al, 1995; Rady et al, 1997; Rady and Ryan, 1999; Hulzebos et al, 2003; Al-Alao et al, 2012), prolonged LOS on ICU (Paone et al, 1998; Yin et al, 2007, Al-Alao et al, 2012) and a proposed variable for predicting reintubation after cardiac surgery (Engoren et al, 1999) which is important to consider.

Overall, 16% of the study population had a diagnosed pulmonary disease e.g. asthma or Chronic Obstructive Pulmonary disease (COPD), the proportion of which did not differ greatly amongst the two groups and is comparable to that found in previous studies (Shroyer et al, 2003). The literature is replete with studies into patients with COPD undergoing cardiac surgery (Higgins et al, 1992; Locicero et al, 1992; Kroenke et al, 1993; Cohen et al,1995; Siafakas, 1995; Spivack et al, 1996; Samuels et al, 1998; Michalopolous et al, 2001; Ferrer et al,2002; Canver and Chanda, 2003; Saleh et al, 2012), which proposes that patients with COPD have an increased risk of PPC's (Smetana et al, 1999; Saleh et al, 2012) and those with severe COPD, defined as FEV1 <50% predicted (Michalopolous et al, 2001; Kroenke et al, 1993) have required prolonged intubation, longer intensive care unit stay and a greater incidence of reintubation (Cohen et al, 1995; Canver et al, 1998; Locicero et al, 1992;Ferrer et al, 2002; Michalopolous et al 2001) and pulmonary complications (Samuels et al, 1998; Bevelaqua et al, 1990).

The severity of a chronic pulmonary condition varies, and is often based on pulmonary function testing, including spirometry and flow-volume loop, and is classified into mild, moderate or severe impairment. However, in 2007, only 6% of patients (n=19) had pulmonary function testing prior to surgery, which did increase to 9.6% of patients (n=42) that were tested in 2009 (p=0.006). Although statistically significant, the findings are too few to generate comparisons to previous literature, but do imply that pulmonary function testing prior to surgery is not a routine clinical requirement within this institution, which appears to conform to previous recommendations in the literature (Smetana, 2003).

Whilst the use of pulmonary function testing appears to be on a somewhat ad-hoc basis, previous studies have conflicting results on the value of using pulmonary function testing as an independent predictor for serious complications (Cohen et al, 1995; Canver et al, 1998; Kroenke et al, 1993). Furthermore, Smetana (2003) advocates that clinicians should not routinely recommend pre-operative spirometry prior to high risk surgery as it is no more accurate in predicting risk than clinical evaluation (Bevelaqua et al, 1990; Kroenke et al, 1993; Bando et al, 1997; Smetana, 2003). With recognition of this, the findings in this study together with that of previous literature appear to support the pre-operative pulmonary function testing be on a selective basis and not as an independent predictor for postoperative complications.

On the other hand, it is necessary to recognise that the number of patients presenting for surgery with diagnosed COPD that were being actively treated for their condition significantly increased from 7.1% in 2007 to 11.8% in 2009 ($p=0.01$). However, it could be argued that although the number of individuals that were not receiving pre-operative treatment for a diagnosed pulmonary condition significantly reduced from 13.8% to 3.1% in 2009 ($p=0.000$), there still remains a small group of patients whose pulmonary condition is not being optimised prior to surgery. The impact of this on clinical outcomes is beyond the scope of this study although could be a recommendation for future research.

Furthermore, the findings from Cohen et al (1995) and Saleh et al (2012) suggest the results from patients undergoing cardiac surgery with severe COPD to be unfavorable, for instance, prolonged LOS in ICU, prolonged intubation and early mortality. Despite this, it could be argued that the current risk stratification model i.e. EuroSCORE do not capture this risk, based on the severity of COPD, and it fails to classify the severity of chronic lung disease, a shortcoming as highlight by Saleh et al (2012).

The characteristics of the study population have shown there to be an increasing number of patients who undergo cardiac surgery with pre-existing renal disease. In 2007, the prevalence of patients whom had known renal failure pre-operatively was 1.0%, which significantly increased to 4.3% by 2009 ($p = 0.01$). However, this is relatively low compared to a prevalence of 12.2% to 17.2% that has been reported previously (Anderson et al, 1999; Chonchol et al, 2007). Pre-operative renal failure has been linked to an increased risk of prolonged endotracheal intubation (Bando et al, 1997; Anderson et al, 1999) and a variable found to predict reintubation (Engoren et al, 1999).

Additionally, regarding heart failure with reduced LV function, there were only subtle differences between the proportions of good, moderate and poor LV function between the 2 years evaluated, and overall 56% of patients are classified as 'Good' LV function which was the only statistically significant increased variable, 31% as 'Moderate' and 13% as 'Poor' LV function. Despite there being no real differences between the two groups, it is important to consider reduced LV function has been highlighted as a potential risk factor linked to the development of postoperative complications following surgery (Weismann, 2004; Filsoufi et al, 2007) and more specifically, pulmonary complications, although this evidence is conflicting (Johnson et al, 2001; Bastos et al, 2011).

Of the sample, 11.8% were current smokers that failed to cease smoking prior to their surgery, and is a factor proposed to increase the risk of complications, particularly pulmonary complications postoperatively (Ngaage et al, 2002; Ashraf et al, 2004; Al-Sarraf et al 2008; Jones et al, 2011) and is associated with prolonged ICU stay and a higher in-patient mortality (Jones et al, 2011).

It is widely acknowledged that the changing profile of the cardiac surgical patient is one that exhibits several co-morbidities. Regarding a patients past medical history, the results demonstrated only those patients with a single system co-morbidity to have risen significantly. Despite this, only subtle differences were apparent in the proportions of co-morbidities in terms of number of system dysfunction between to 2 groups, which was not significant. Although it is important to consider the majority of patients undergoing cardiac surgery have 2 or 3 systems of chronic co-morbidities, and 16.8% of patients consistently underwent cardiac surgery with chronic co-morbidities of greater than 4 systems of dysfunction. This service evaluation has demonstrated that patients undergoing surgery present with an array of chronic conditions, and has perhaps verified that patients are indeed "sicker" undergoing cardiac surgery today.

5.5.2 Operative Data

Although the most common cardiac surgical procedure is CABG, it appears as though there is a steady increase in the proportion of isolated valves being carried out, increasing from 15.8% of the workload to 20.0% ($p=0.03$). Additionally, more complex procedures such as combined CABG and valve surgery and surgery involving the thoracic aorta appeared to increase in number from 2007 to 2009, although are not significant. The increased in the proportions of complex procedures being undertaken together with the 'higher risk' patient profile, adds weight to the notion of greater operative risk as predicted by Ferguson et al (2002).

With regards to preoperative variables and demographics, the results have shown there to be little difference across the two timeframes and the proportions of the variables evaluated remained much the same.

5.5.3 Principal Findings: Clinical Outcomes

As part of the aim for Phase I of this chapter, in conjunction with Donabedian's framework for service evaluation, the trends relating to output/outcomes were to be defined. This retrospective audit of 736 patients who underwent cardiac surgery have demonstrated that most patients have an uneventful recovery. In 2007, 55.9% of patients (n=185) had an uncomplicated pathway of care, which marginally reduced to 54.7% of patients (n=222) in 2009. However, inevitably for some patients, serious complications will occur.

Overall, between the two groups, 14 patients died, thus, the observed mortality rate in 2007 was 1.3% (n=4) which rose to 2.4% (n=10) in 2009 (p=0.109) resulting in an overall mean survival rate of 98%. Despite there being a slight increase in mortality rates from 2007 to 2009, the results found this to be consistently lower than the national average for mortality, which was 3.1% over the same period.

Although the majority of patients were extubated within 7-12 hours postoperatively, 14.8 % of patients in 2007 were extubated sooner, i.e. 3-6 hours following their surgery, which significantly increased to 39.9% in 2009 (p=0.000). This is consistent with practice reported from other centres (Johnson et al, 1997; Yende & Wunderink, 2002; Hawkes et al, 2004). This reflects the change in practice over the past few years, and confirms that clinical practice is adhering to a culture of early extubation as suggested in the literature (Johnson et al, 1997; Yende and Wunderink, 2002; Hawkes et al 2004).

However, the service evaluation has demonstrated that a small number of patients were not extubated within the optimal timeframe and for 1.7% of patients in 2007 who required ventilation beyond 48 hours. This figure marginally increased to 2.0% in 2009. Although this is not statistically significant, the figures remain low in comparison to other series that have reported an incidence of PMV from 2.6% to 22% (Arom et al, 1995; Kollef et al, 1995; Spivack et al 1996; Yende & Wunderink, 2002; Shroyer et al, 2003; Wynne & Botti, 2004). Additionally, the discrepancy that appears to exist within the defining criteria of PMV in the literature, ranging from >24 hours to ≥7 days (Yende and Wunderink, 2002; Pappalardo et al, 2004; Rajakaruna et al, 2005; Murthy et al, 2007) makes it problematic to produce a valid comparison. Nevertheless, for those small group of patients who required PMV and hence a prolonged length of stay, considerable financial implications for the organisation need to be considered.

In view of this, within the current economic climate, the length of stay on an intensive care unit is often a subject of clinical discussion, as a prolonged length of stay has been associated with a significant portion of healthcare costs (Tuman et al, 1992). In 2007, the mean stay on CITU following surgery was 1.18 days + 5.130SD, which significantly increased to 2.05 days +9.059SD (p=0.05), suggesting that patients are staying longer during the initial postoperative period thus requiring a more intensive level of medical care during the first 24 to 48 hours. Following discharge from CITU, the overall the postoperative stay in CITU and CHDU significantly decreased from 9.96 days +16.611 to 4.69 days +9.453SD in 2009, suggesting once a patient is discharged from CITU, they proceed to discharge to the ward environment quicker in 2009.

There appears to be a trend in relation to length of stay and readmission rates to CITU, as it is evident that whist the LOS in 2007 was shorter, the incidence of readmission at 2.6% (n=8) was greater, than in 2009. Although this is less than the range of readmission of 2.3% to 5.9% as previously described by Kollef et al, 1995; Bardell et al, 2003; Vohra et al, 2005. It is important to address however, the findings were not statistically significant and it appears there only slight differences exist between the two groups with relation to readmission.

5.5.4 Principal Findings: Post-Operative Complications

In evaluating the output/outcomes of the service, the incidence of postoperative complications was determined. The findings have demonstrated that the most common complications following cardiac surgery to be respiratory and cardiac.

Cardiac complications in the present study arise as a complication of their original surgery, this includes, postoperative bleeding, arrhythmias, surgical site infection, cardiac arrest, pericardial effusion, cardiac tamponade or MI. In 2007, 13.6% of patients (n=42) suffered cardiac complications following surgery, and this significantly increased to 21.2% (n=104) in 2009 (p=0.000).

In 2007, the incidence of PPC's was 24.3% and in 2009, 21.9% of patients. In the interest of clarity, pulmonary complications included were pneumonia, atelectasis, respiratory failure requiring mechanical ventilation or non-invasive ventilation, pleural effusion, pneumothorax, bronchospasm, a diagnosed chest infection requiring intensive chest physiotherapy and antibiotic treatment. Those patients with microatelectasis, unexplained pyrexia or dyspnoea, a criteria as defined by Hulzebos et al (2003) were not included. Although the incidences of PPC's in this study do not differ greatly between the two groups, the findings provide substantiate support to the view that one fifth of patients, on average develop PPC's following cardiac surgery. These results apparently contrast with those reported by Hulzebos et al (2003) and Rady et al (1997) however are in agreement with Kollef et al (1997) and Laizo et al (2010) who similarly found that pulmonary complications were the most frequently occurring complication following cardiac surgery.

Furthermore, the literature supports an association between pulmonary complications and increased mortality and morbidity, with increased LOS. However, the findings of this evaluation highlights the need to explore PPC's and their impact on clinical outcomes in greater detail. This will be further addressed in the discussion of results of Phase II.

In light of this data, although the vast majority of patients do have an uncomplicated postoperative recovery and the trend of the incidence of PPC's remains unchanged from 2007 to 2009, nevertheless, on average, 20% of the cardiac surgical population consistently develop PPC's. This is an important implication arising from the findings of this audit which warrants further investigation.

Regrettably, the National Adult Cardiac Surgical Audit fails to provide information relating to the incidence of complication rates over the two timeframes, and consequently are unable to generate a comparison.

In summary, the information gathered from Phase I of this service evaluation has defined the local population undergoing surgery. In relation to age and gender profiles and clinical outcomes relating to mortality rates, the findings have been compared to the national profile. They are suggestive that the local sample cohort can be considered representative of the cardiac surgical population nationwide.

The trends within the current setting in relation to outcomes are now verified, and the profile of the cardiac surgical patient have been described. Whilst the majority of patients proceed through the surgery without experiencing adversities, there are a small group of patients that do not, and for some, a degree of postoperative morbidity is inevitable.

Overall, there was little differences between the two cohorts, though, the findings from the preoperative characteristics do confirm that at this institution, cardiac surgery is being offered to an older patient group, presenting with chronic co-morbidities and also more complex procedures are being performed. Even though the rate of postoperative complications remain low in comparison to the evidence base, pulmonary complications remained the most frequent and consistent complication overall, accounting for, on average, 20% of complications exhibited by the cohort. This has confirmed the findings from the literature in the narrative and systematic review that have reported pulmonary complications to be the most frequently occurring.

Hence, there was a clinical need to delve into PPC's to investigate these findings in a greater depth and to define its influence on clinical outcome and service delivery, as well as to determine the risk factors for the development of PPC's. It was therefore prudent to focus on those individuals who developed PPC's, to determine the extent of which preoperative characteristics are predisposing factors, which was the main focus of Phase II of this chapter.

Phase II set out to examine the impact of PPC's on clinical outcomes after cardiac surgery and also to explore the contributing factors within the patient profile and identify characteristics that potentially influence the development of this complication.

5.5.5 *Incidence of PPC's*

This evaluation showed an incidence of PPC's was 20.2% (n=166). Other series have reported an incidence of PPC's of 12% to 33% (Rady et al, 1997; Hulzebos et al, 2003). In light of this data, although the majority of patients do have an uncomplicated postoperative recovery, nevertheless, 20% of the cardiac surgical population develop PPC's, which is an important implication arising from this study. A limitation of the study however, was that the proportion of patients that developed each criteria within the definition of PPC's i.e. pneumonia, pleural effusion etc. was unknown.

5.5.6 The Influence of PPC's on Clinical Outcomes

This retrospective review of 736 patients who underwent cardiac surgery has demonstrated that 50.0% of patients (n=412) had an uncomplicated postoperative recovery. Within the current economic climate, prolonged length of stay on ICU is associated with increased healthcare costs (Tuman et al, 1992; Christakis et al, 1996). The results of this study showed that patients spent on average 1.68 days on CITU (SD+7.667), which is less than 2.5 ±4.0 days previously reported (Tuman et al, 1992). The average post-op CITU/CHDU stay was 6.95 days (SD+13.269) and the overall stay was 12.12 days (SD+15.067), considerably longer than reported by Wynne in 2003 (Wynne, 2003).

A crucial aim of phase II was to explore the impact of PPC's on clinical outcome. Those patients who developed PPC's spend on average, 5 days longer on CITU, (5.04 days vs. 0.4 days) which was statistically significant (p=0.000) and also had a significantly longer postoperative length of stay i.e. CITU and CHDU combined of almost 3 times longer (13.49 days vs. 4.5 days; p=0.000) than those without PPC's. The prolonged length of stay associated with those patients who developed PPC's in this study is considerably more than 10 days as previously reported (Welsby et al, 2002). Tuman et al (1992) demonstrated a 2.5 ±4.0 day's intensive care stay for those patients who had an uncomplicated recovery compared to 7.0 ± 9.6 days for those who suffered complications postoperatively. Although in this study, the mean total length of hospital stay was double for those who developed PPC's (18.6 days vs. 8.94 days) which was statistically significant (p=0.000), it is prudent to recognise that the overall hospital stay can be influenced by variables such as deranged INR levels, social issues etc.

The majority of this cohort of cardiac surgical patients (n=585, 82.5%) were extubated within 12 hours after surgery and no difference was found in the extubation time between the PPC and non-PPC groups. This suggests that PPC's did not occur during the initial period of mechanical ventilation, or did not delay extubation as patients satisfactorily fulfilled the extubation criteria. Another plausible explanation is that patients developed PPC's following decannulation.

5.5.7 Patient Characteristics

Patient characteristics were examined to identify any contributing factors that appear to influence the development of PPC's. The majority of the patients were male with 26.6% being female and presenting for coronary artery by-pass surgery. Despite female gender to be a proposed risk factor correlated with an increased risk for the development of PPC's in the literature (Poelaert and Roosens, 2009; Sawatzky and Naimark, 2009), those patients who developed PPC's were mostly male.

The mean age of patients undergoing surgery was 68.14 years (SD+10.508). However, as previously acknowledged in the service evaluation Phase I, co-morbidity and complications are proposed to increase with age (Rodriguez et al, 2002; Poelaert and Roosens, 2009). Interestingly, in this study, the mean age of patients who developed PPC's was 69.3 years, which is slightly older than 67.14 years for those patients who had an unremarkable recovery. Nevertheless, these findings seem to contradict the belief that elderly patients have a greater risk for developing pulmonary complications following cardiac surgery.

Of the 16% of this study population that had a diagnosed pulmonary disease e.g. asthma or COPD, and the literature that is suggestive of a correlation between COPD and an increased risk of PPC's (Cohen et al, 1995; Christakis et al, 1996; Samuels et al, 1998; Smetana, 1999; Michalopolous et al, 2001; Canver and Chanda, 2003; Saleh et al, 2012), contrary to these findings, this study, patients who developed PPC's had no history of pulmonary disease. This is contradictory to the literature suggesting COPD as a risk factor to the development of PPC's.

Other non-surgical risk factors identified in the literature to be predisposing factors for PPC's include smoking (Ngaage et al, 2002; Ashraf et al, 2004; Al-Sarraf et al, 2008) and a pre-existing renal disease, (Christakis et al, 1996; Anderson et al, 1997; Chonchol et al, 2007) however, they do not appear to be influential factors for the development of PPC's in this study.

Although, the association between impaired LV function and pulmonary complications has been discussed from a variety of perspectives (Arom et al, 1995; Christakis et al, 1996; Dimopoulou et al, 1998; Engoren et al, 1999; Rady & Ryan, 1999; Johnson et al, 2001; Weissman, 2004; Poelaert and Roosens, 2009; Kortekaas et al 2012*)*. In this study those patients who had an uneventful recovery most commonly had a "good" (EF >50%) LV function, however those patients who developed PPC's had a "moderate" LV function (EF 30-50%). The distinct difference certainly strengthens the possible association between worsening LV function and PPC's. Therefore, when reviewing the patient characteristics, the analysis of the patient profiles demonstrated LV function to be the isolated pre-operative characteristic that differed between those who developed PPC's and those who did not.

The association between reduced cardiac function and pulmonary impairment has been previously discussed (Johnson et al, 2001; Weissman, 2004; Dimopoulou et al, 1998; Kortekaas et al, 2012). From a pathophysiological perspective, it is thought that low cardiac output generates an increase in pulmonary capillary pressure and lung water and can lead to mild congestive heart failure and cardiogenic pulmonary oedema (Weissman, 2004). Additionally, airway narrowing and swelling of the bronchial mucosa may be precipitated by the changes in pulmonary and bronchial vascular pressures in response to left ventricular failure (Snashall and Chung, 1991; Dimopoulou et al, 1998). Subsequently an impairment in cardiac function has been found to have an impact on patients resting pulmonary function, reducing mean lung volumes (Johnson et al, 2001) and in particular those patients with severe left ventricular dysfunction, defined as an ejection fraction (EF) of <35% (Rady and Ryan, 1999) are thought to have an increased risk of developing respiratory dysfunction (Christakis et al, 1996).

Although cardiac ventricular dysfunction has been previously found to be associated with a higher risk of pulmonary dysfunction, on the other hand, LV function has also reported to be associated with prolonged LOS on ITU (Christakis et al, 1996; Kortekaas et al, 2012). The present study supports this, as the findings imply a possible relationship between LV performance and length of stay. Patients with "Good" LV function and did not develop PPC's, stayed in ITU on average 0.4 days postoperatively, compared to those who patients with a "Moderate" LV function, who did develop PPC's and had a much longer mean ITU stay of 5.04 days. The results propose that LV function is a potential risk factor for the development of PPC's following adult cardiac surgery and further to this, LV function could also be a predictor of prolonged length of stay in intensive care.

5.6 Summary

Phase II of this chapter, has generated the data surrounding the effect of the development of PPC's in the clinical context to be examined. The impact of PPC's on clinical outcome in the study population is profound. This component has demonstrated that one fifth of patients who undergo cardiac surgery will develop PPC's. The patient profile analysis has highlighted that LV function was the only isolated pre-operative characteristic that differed between those who developed PPC's and those who had an uneventful recovery. Thus, these findings have identified the potential causal factors for PPC's and the bearing of this complication on clinical services has addressed some elements of the overall aim of this thesis. From this, the discoveries now warrant further research and how these findings could inform physiotherapy practice including the potential opportunities to utilise LV function as an outcome measure to screen for adverse outcome will now be considered in the discussion chapter (6.0).

6.0 Discussion Chapter

6.1 Introduction

The primary aim of this project was to examine the nature and identifiable causal factors of postoperative pulmonary complications following adult cardiac surgery, so as to inform physiotherapy practice in patients identified as high risk. PPC's that develop following cardiac surgery are problematic in a patient's recovery, requiring a longer than anticipated length of stay in hospital which in turn can increase this risk of postoperative morbidity and mortality. From a clinical perspective the management of reducing postoperative complications is challenging and currently the physiotherapy treatment of PPC's has not been tailored to those individuals that are at greater risk for the development of this complication.

This chapter will summarise and discuss the findings of the project together with making comparisons to the body of literature. It will examine the clinical data to support informing change within physiotherapy practice for those individuals identified at greater risk for PPC's. It will also consider the application of the findings in terms of their clinical relevance.

6.2 Principal Findings

The main outcomes of this study revealed that on average, 20% of adult cardiac surgical patients will develop PPC's. The service evaluation determined that this number has not risen over recent years, nonetheless, has remained consistent throughout the study period. Furthermore, the impact of PPC's on clinical outcomes were evaluated and revealed that PPC's following surgery can significantly increase the necessary ITU stay, thus impacting on the overall hospital stay by as much as threefold. This has confirmed a relationship to exist between prolonged ITU stay and PPC's. LV function was found to be the isolated preoperative characteristic to differ between those who developed PPC's and those who had an uneventful recovery. These principal findings have fulfilled the research questions that were initially proposed in the introduction chapter. Moreover, based on this information, the potential introduction of physiotherapy led clinical strategies to avert PPC's in the future will be discussed in this chapter.

6.2.1 Risk factors for the development of PPC's following cardiac surgery

In order to identify those patients at greater risk for the development of PPC's, there was firstly a need to gain a robust understanding into the risk factors inherent within a patient profile presenting for cardiac surgery. The Systematic Review (Chapter 2.0) was performed to highlight the pertinent research undertaken into risk factors and patient characteristics for the development of PPC's and by utilising the CASP critical appraisal tool ensured those papers included were also of high methodological quality. The outcome of the systematic review provided robust literature surrounding the prediction of complications, and a means of predicting respiratory complications by the identification of risk factors. Age, gender, COPD, history of cigarette smoking, obesity and heart failure were the universal risk factors identified for their association with PPC's following surgery.

Following this, it was then prudent to gain a greater understanding of PPC's in the wider context of postoperative recovery following cardiac surgery. The Narrative Review (Chapter 3.0) was then performed to examine postoperative complications in determining morbidity and mortality, in addition to evaluating the role of physiotherapy in addressing or predicting PPC's. It was important to determine if a prediction model or screening tool currently exists for the prediction of PPC's that could be used to inform physiotherapy practice at ABMU. Within the narrative review, it was clear that few prediction models exist. Prediction models can be beneficial for clinicians in the planning of services, by facilitating a timely assessment and treatment intervention to those patients who would benefit the most, thus, enabling resources to be utilised in a more efficient manner. Many of the studies appraised within the literature centered on the prediction of adverse clinical outcomes following cardiac surgery. Those conducted by Spivack et al (1996) and Bando et al (1997) sought to determine factors for the prediction of PMV postoperatively, whilst Bardell et al (2003), Vohra et al (2005) and

Litmathe et al (2009) investigated readmission to ICU as their main outcome. Others researchers including Laizo et al (2010) identified prolonged ICU stay as their primary focus and Kollef et al (1997) examined risk factors for hospital-acquired infections following cardiac surgery. Many of these were observational based studies and thus an inherent level of bias could not be eliminated. Further, the small sample cohorts were isolated to CABG surgery and not the cardiac surgical population as a whole and thus would not inform changes within physiotherapy practice at the current centre in the future. Despite this, the aim of understanding the nature and causal factors for the development of PPC's following cardiac surgery was extensively explored in both of the literature review chapters.

Although, a concurrent theme when examining risk factors for adverse outcomes in the above papers was evident. Pulmonary complications were consistently found to be the most frequent and problematic, which is in agreement with the findings of this project that has revealed pulmonary complications to be the most common of complications following cardiac surgery at the current institution. PPC's following cardiac surgery are crucial to address, as once develop, they call for increased length of stay, increased intensity of treatment and resources (Kollef et al, 1997; Leal-Noval et al, 2000; Naughton et al, 2003; Laizo et al, 2010; Topal and Eren, 2012). Frequently the literature emphasized the clinical need for strategies to overcome these complications, including physiotherapy.

The physiotherapy based interventions reviewed in the narrative review, were largely based upon selected patients undergoing isolated CABG surgery, and not applicable to the wider cardiac surgical population, as previously found in the literature. Additionally many of these studies compromised their methodological quality due to their recruitment of small sample cohorts evaluated. However, several attempts have been made to assess the effectiveness of physiotherapy, either to reduce more generalised PPC's as studied by Stiller et al (1994), Crowe and Bradley (1997), Brasher et al (2003), Dias et al (2010) or aimed at reducing more specific postoperative complications, such as atelectasis (Johnson et al, 1996).

Perhaps the most relevant research undertaken into the prediction of PPC's following cardiac surgery and of similar nature to the current project is the work of Hulzebos et al (2003). The authors postulated a risk model based upon preoperative patient factors and subsequently utilised these findings in order to classify patients into high and low risk for the development of PPC's. The preoperative characteristics evaluated were also similar to the current project including age, gender, PFT's and smoking history with the exception of BMI, diabetes and a productive cough. The results confirmed age >70 years, productive cough, diabetes and a history of cigarette smoking to be predictive factors for the development of PPC's. In light of this research, it could be argued that the necessary work into determining a prediction strategy had previously already been established by Hulzebos and associates in 2003 and therefore could inform physiotherapy services at the current clinical setting that this research was conducted. However, during the critical appraisal process in the systematic review, it was discovered that the authors lacked clarity in the determining effects of the preoperative risk factors and their association with PPC's. Moreover, there was uncertainty surrounding the statistical analysis of the results. Additionally, the work carried out by Hulzebos et al (2003) could only be applicable to those patients undergoing CABG surgery and consequently was not deemed suitable for consideration of its introduction at the current institution. This theory reinforced the important need for further investigation and the application of this knowledge that could then be utilised to inform physiotherapy services for patients identified as high risk for PPC's that would have relevance for all cardiac surgical interventions. This encapsulates the aim of the current programme of research. The principle findings will not only add to the existing evidence base but will contribute to the work of Hulzebos et al (2003), with its findings being generated from a much larger cohort of 736 patients, as well as being applicable to the whole cardiac surgical population. This is believed to be a strength of this research.

Furthermore, the physiotherapy evidence reviewed found there to be considerable variability amongst clinical protocols for assessment and treatment procedures. Therefore, the physiotherapy literature for specific techniques aimed at reducing PPC's is somewhat speculative, as the appraisal process revealed the evidence to be conflicting and unproven. However, it seems as though a key component thought to be influencing this is the lack of clear objective measures that appeared to be absent within the body of physiotherapy literature.

Overall, the physiotherapy based research is to some extent suggestive that the provision of physiotherapy treatment following routine cardiac surgery to be unnecessary (Stiller et al, 1994; Johnson et al, 1996; Brasher et al, 2003). Nevertheless, there is a case for adopting a more targeted approach to those individuals thought to be at greater risk for the development of pulmonary complications following surgery. Subsequently 'early intervention trials', providing physiotherapy during the crucial immediate postoperative period of mechanical ventilation were carried out by Eales et al (1995) and Patman et al (2001). Although both of these studies conclude that the provision of an early intervention strategy did not alter clinical outcomes, they are only representative of routine and uncomplicated pathway of care. Therefore, it could be argued and postulated that other sub-groups of the cardiac surgical population, thought to be at greater risk for PPC's, may respond differently to an early intervention service and this warrants further exploration. The potential opportunities to introduce such strategies will be discussed later in this chapter.

Additional risk factors that were introduced early on in this thesis were the potential impact of psychological variables. A high level of preoperative depressive state and anxiety appears to be predictors of postoperative psychological outcome, including a patients psychosocial functioning and QOL, and increased mortality (Rymaszewska et al (2003), Tully et al (2008); Rothenhäusier et al (2005). It is pertinent to address how these psychological variables may have been present in the group of patients studied in this programme of research but were not assessed, as it was felt they were beyond the scope of this project. By preference, it was necessary that evidence relating to patient characteristics and risk factors would focus more on clinical outcomes and physiological objective measures as the information yielded from this strategy would be more suited to the clinical population within the constraints of this work. However, given the possible association of psychosocial factors and outcome, it is recommended that future research should further explore this association, and aim to improve the psychological evaluation and management of patients undergoing cardiac surgery by the hope of improving QOL and outcomes (Pignay-Demaria et al, 2003). It is thought that preoperative assessment of patients can help identify patients at risk for levels of postoperative anxiety and depression (Rymaszewska et al, 2003). Strategies such as preventative counselling and psychiatric interventions to enhance a patients 'locus of control' by means of coping strategies can reduce emotional distress and the resultant economic costs (Rymaszewska et al, 2003; Tully et al, 2008).

Subsequently, based on the substantial evidence regarding risk factors and clinical outcomes generated from the literature review chapters, the rationale and framework to consider the application of this evidence to the local cardiac surgical population was directed. Therefore, the findings from the literature review chapters facilitated the design of the audit data collection tool that was utilised in the service evaluation chapter. This evidence determined what information i.e. patient characteristics and postoperative outcomes would be extrapolated from the patient records. Although, the literature surrounding BMI as a risk factor for complications following cardiac surgery were centred upon individuals that were extremely obese with a BMI of greater than 40, which does not conform to clinical practice at the current setting. Therefore it was decided to exclude this variable from selection in the service evaluation.

6.2.2 Service Evaluation

The service evaluation of surgery undertaken at the cardiac centre produced a greater understanding into PPC's following surgery, as it provided a valuable insight into patient characteristics, surgical activity and clinical outcomes. The conceptual and quality framework of Donabedian (1988) introduced in Chapter 4.0, has enabled the service to be evaluated in a systematic manner, aiding the local population undergoing cardiac surgery to be defined. Although, it is important to acknowledge that the design of the evaluation was largely determined by the resources available. The results can be used as a benchmark against which the effectiveness of future interventions can be measured and is therefore extremely relevant to the clinical setting.

Based on the information from the UK National Adult Cardiac Surgery Audit provided by SCTS and NICOR, comparisons have been made from the local population to the national picture with respect to age, gender and surgical outcomes. Although patients undergoing cardiac surgery at AMBU appear to be older than that national average, mortality rates on average are lower than reported elsewhere, the findings of the service evaluation could be considered as representative of the general cardiac surgical population. This level of comparison is central to confirming if the local population is representative of the national profile, which is an important step in ensuring that the local patients requiring cardiac surgery in this evaluation were not unique. Furthermore, in terms of the relevance of findings of this project, the potential for a wider dissemination of the results would be possible if they are applicable to the national caseload.

At the outset, it was perceived that the local population requiring cardiac surgery, was one that was older, frailer and presented with increasing co-morbidities. The population evaluated found there to be statistically more males presenting for surgery in 2009, 73.6% in 2007 vs. 73.1% in 2009 (p=0.002), and females only accounting for approximately 30% of the surgical cohort. Both the literature and the recommendations from the SCTS put forward the female gender to be at higher risk for the development of PPC's and prolonged LOS (Sawatzky & Naimark, 2009), although these were not found to be a determinant for increased mortality (Reid et al, 2011).

In relation to age, there appears to be almost equal proportions of patients either aged below 70 years or above, with a significant increase in the amount of patients less than or equal to 70 years as seen in 2009 (49.4% vs. 56.3%; p=0.000). In this study, patients aged >70 years were classed as 'elderly' which is in accordance with Paone et al, 1998; Rodriguez et al, 2002; Yin et al, 2007. However, as previously recognised, there is a disparity in the definition of 'elderly' in the body of previously published literature. Despite this, the mean age of patients locally are found to be older than the mean age of 66 years old reported in the national audit for cardiac surgery.

Although this suggests that the majority of patients at this clinical centre to be perhaps younger than initially perceived, it is also important to acknowledge that there is a consistent group of patients over the age of 80 years undergoing surgery. It was found that 14.1% of patients were >80 years in 2007, and in 2009 they accounted for 9.6% of the sample. However, this is not of statistical significance although it is in contrast to that reported previously by Faggian et al (2011). This would imply that the increased proportion of octogenarian patients undergoing cardiac surgery locally is higher than reported elsewhere and seems to support the notion that at ABMU cardiac centre, consultant surgeons are operating on progressively older patients. The literature does however support this finding, as elderly and octogenarian patients were found to have acceptable levels of mortality (Faggian et al, 2011). Although on the other hand, they were found to be at greater risk for postoperative morbidity, as co-morbidities have been found to increase with age (Rodriguez et al, 2002) including increasing rate of complications, prolonged duration of mechanical ventilation and increased LOS (Paone et al, 1998; Yin et al, 2007; Al-Alao et al, 2012). Interestingly, those individuals who developed PPC's were found to be on average 69.3 years and therefore does not support the notion that elderly patients are a greater risk of developing this complication.

Many patients requiring cardiac surgery presenting with cardiovascular disease often exhibit other medical problems. In this study, the findings suggest that the majority of patients undergoing surgery to have at least 2 or even 3 systems of co-morbidities, and for approximately 16% of patients, this exceeds over 4 systems of dysfunction. It is important to recognise how these findings verify the initial concept that patients are 'frailer' or 'sicker' prior to their operative procedure.

More specifically and perhaps surprisingly, over 50% of the patients requiring cardiac surgery did not present with a degree of heart failure and were assessed preoperatively as having 'Good' LV function. However, for approximately 30% of patients who were classified as 'moderate' LV function and 13% as 'poor, inherently had a reduced LV ejection fraction. Heart failure and its association with pulmonary function has been confirmed by Johnson et al, 2001, although worsening LV function has not found to be associated with increasing rates of PPC's (Bastos et al, 2011).

PFT's were assessed for only 6.0% of patients in 2007 as part of their preoperative assessment, which increased to 9.6% in 2009 (p=0.006). As the numbers of patients tested were limited, it appears that PFTs prior to cardiac surgery in the current setting are requested on a case-selection basis. This level of testing is supported by Smetana (2003) who believes that routine preoperative PFT's to be no more accurate than clinical evaluation practice. It is relevant however to discuss how there is an evidence base to support the use of PFT's preoperatively. Hulzebos et al (2003) put forward spirometric data as a valuable measurement in providing data in relation to a 'protective factor' for the development of PPC's.

This service evaluation of cardiothoracic services therefore offers a recommendation that based on the body of literature and the few numbers tested within this cohort, that the rationale for the use of PFT's in the current clinical setting be reconsidered. This would potentially refine the referral criteria for PFT's based upon the most recent evidence. Furthermore, if it were to be decided that PFT's would become a routine requirement, it potentially could provide valuable information on markers of respiratory dysfunction preoperatively. As previously recognised in the service evaluation chapter, there were a small group of patients who were not receiving treatment for a pre-existing pulmonary condition, which accounted for 13.8% of patients in 2007 and 3.1% in 2009. Therefore it could be argued that by having PFT's prior to cardiac surgery, this may provide an opportunity to optimize a patients respiratory potential. Although, it should be highlighted that this warrants further research to explore fully before any conclusions can be made.

Furthermore, Adabag et al (2010) recommend that PFTS's to be carried out routinely prior to cardiac surgery, particularly advocating that it aids with the reclassification of COPD status. They further propose that PFT's provide crucial information which they argue that current risk stratification models do not capture. Therefore this is a potential shortcoming of the current EuroSCORE risk stratification system, as although chronic lung disease is included, it is not further categorised into the degrees of severity. As postulated by Saleh et al, (2012) the generic definition included in risk evaluation is not one that reflects the disease severity. Although, it has been demonstrated that risk stratification has evolved over time, it could therefore be proposed based on the clinical relevance of this information, there is justification and a recommendation to revise this once again.

Overall, the primary findings from the service evaluation demonstrated there to be some differences between patient profiles over the two groups as previously discussed. However the key discoveries were in relation to the significant differences found for ITU LOS and the overall LOS. In 2007, the mean ITU LOS was 1.18 +5.130SD days, which significantly increased to 2.05 +9.059SD days ($p=0.005$), suggesting that patients are requiring an intensive level of postoperative care following their surgery in 2009 demonstrated by this increase in LOS. This could imply that patients are sicker following surgery. In comparison to other centers, the mean LOS found in this evaluation was considerably less than 4.16 ± 3.76 days as previously reported by Laizo et al (2010), and 2.3 ± 1.8 days for patients who had an uneventful recovery as found by Kollef et al (1997). This requirement for an increasing LOS in ITU has demonstrated the importance of addressing any influential factors that can have a detrimental impact on service delivery and performance outcomes. This reinforces the importance of addressing complications at the earliest point so that their detrimental effects are minimised.

Although, it is apparent in terms of postoperative recovery that over 50% of patients will proceed through cardiac surgery at ABMU Cardiac Centre without experiencing adversities. However, further results generated from the service evaluation include the main complications to be respiratory and cardiac in origin, which is parallel to the findings of Bardell et al, 2003; Vohra et al, 2005; Michalopolous et al (2006); Litmathe et al, 2009; Rahmanian et al (2010) and Lola et al (2011). PPC's in this evaluation were classed as atelectasis, pneumonia/consolidation, respiratory failure, chest infection, pleural effusion etc. the incidence of which across the two audit groups were similar, 24.3% in 2007 and 21.9% in 2009 (p=0.214). The incidence of PPC's in this study is considerably greater than the range of 9.1% to 13% as previously reported (Canver & Chanda, 2003; Filsoufi et al, 2008; Rahmanian et al, 2010; Topal and Eren, 2012). Although, despite the results not being statistically significant, PPC's were found to be the most frequently occurring complication and hence, for the service, the most problematic. This strengthens the clinical relevance of this project to address this as a constant issue for concern.

Secondly, cardiac complications arose following the original surgical procedure, including arrhythmias, cardiac arrest, weaning from IABP, re-exploration for bleeding, PPM, surgical site infection etc. which significantly increased from 13.6% to 21.2% (p=0.000). Though such complications are resulting from the surgery, it demonstrates the complexity or "risk" of cardiac surgery for the patients.

Additionally, renal complications were found to significantly increase, from 3.2% in 2007 to 5.6% in 2009 (p=0.05) resulting in a greater number of patients requiring haemodynamic filtration as a temporary form of dialysis which is only delivered on an intensive care unit. All of the complications discussed require an increased length of stay on intensive care and may be a plausible explanation for the prolonged LOS on CITU as seen in 2009.

Other valuable information gained from this evaluation was in relation to clinical outcomes including the time to extubation following surgery. The results indicate the majority of patients were extubated from mechanical ventilation within 7 to 12 hours, which is consistent with the literature (Hawkes et al, 2004; Yende & Wunderink, 2002; Johnson et al, 1997). For some, expediting this process was seen for 14.8% of patients in 2007, who were extubated within 3 to 6 hours postoperatively, which significantly increased to 39.9% in 2009 (p=0.000). It could therefore be argued, that to a certain degree, the results suggest 'rapid recovery' or an enhanced postoperative recovery to be existing within clinical practice where feasible.

On the other hand, PMV was a major course of postoperative morbidity for 1.7% of patients that marginally increased to 2.0% in 2009, which failed to reach a level of significance (p=0.405). The incidence of PMV would clearly result in a prolonged ITU stay and another plausible rationale for the increased LOS in 2009, however, is less than 8.3% as previously described in the work of Spivack et al (1996).

Interestingly in light of these findings, it could be argued that a trend has emerged. Over the two study periods, the results indicate an increasing trend towards reintubation and the need for a tracheostomy that requires a slower weaning process from mechanical ventilation. This could also explain an increased length of stay in ITU overall in 2009. In accordance with this, the level of readmission rates were lower in 2009 (1.0% vs. 2.6). It seems likely that this prolonged ITU stay did not result in patients being readmitted when they deteriorated, as more patients were already receiving a higher, more intense level of care in ITU at that time, and thus may explain the reduce readmission rates.

This service evaluation has provided a constructive foundation to evaluate the current cardiac surgical service and from this, it is now paramount to consider where future developments of the service should be focused. In relation to the aim of this thesis, fundamentally, this service evaluation has provided the context for informing physiotherapy practice. In light of these findings, from a clinical perspective a debate can be generated. If the current level of physiotherapy service provisions has remained consistent throughout the study period, and the level of PPC's in addition to other adverse respiratory outcomes are comparable, it makes one boldly question if the current physiotherapy service is effective, and therefore is it required? The findings of the service evaluation therefore questions the need for routine physiotherapy to prevent complications following cardiac surgery. This notion is in agreement with that previously proposed by Stiller et al (1994) and Brasher et al (2003).

6.2.3 PPC's

On closer examination, the overall incidence of PPC's was 20.2% (n=166), which is considerably greater than the reported 2.6% to 13.0% in the literature (Stiller et al, 1994;

Crowe & Bradley, 1995; Brasher et al, 2003; Canver & Chanda, 2003; Filsoufi et al, 2008; Rahmanian et al, 2010; Topal and Eren, 2012). Following this it was decided to compare those patients who developed PPC's and those who had an uneventful recovery.

The principal finding relating to the development of PPC's, were regarding clinical outcomes. Those patients who developed PPC's stayed on average 5.04 days in ITU and those patients who did not, had a mean ITU LOS of 0.4 days. In comparison to the LOS previously stated by Kollef et al (1997) patients who developed infections, most commonly were respiratory, required an ITU stay of 7.8 ± 8.0 days vs. non-infected patients with a LOS of 2.3 ± 1.8 days, which is higher than the findings in this study. Nevertheless, for each cardiac centre, any factors that significantly influence LOS are essential to address. The prolonged LOS on ITU at ABMU Cardiac Centre for those patients who developed PPC's was also evident the postoperative stay as a whole, which increased from 8.94 days to 18.6 days if a patient developed PPC's following cardiac surgery. All of the differences in clinical outcomes with respect to PPC's were found to be statistically significant.

From the perspective of patient characteristics, in this evaluation it was clear from the results that age, gender, history of COPD, PFT's, history of smoking, renal history or PMH, were not advocated as risk factors for the development of PPC's. This outcome was unexpected, as the results appear contrary to many of the studies evaluated within the literature chapters.

Neither the development of PPC's was found to be attributable to the type of surgical procedure undertaken, as both patients who developed PPC's and those who did not, most commonly underwent CABG surgery. This is in contrast to the literature surrounding CABG surgery involving harvesting of the internal mammary artery and breaching an intact pleura consequently making a patient more susceptible to pulmonary dysfunction (Matsumoto et al, 1997).

However, it could be argued that regardless of the cardiac surgical procedure carried out, PPC's have been associated with general anaesthesia creating a ventilation/perfusion mismatch and thus an impairment in pulmonary function parameters following surgery (Brasher, 2003; Wynne & Botti, 2004). Furthermore, CPB has been consistently thought to be a contributory factor for the development of pulmonary dysfunction (Rady et al, 1997; Andrejaitiene et al, 2004; Wynne & Botti, 2004; Zupancich et al, 2005). Additionally the lung ventilation and circulatory arrest components of CPB during hypothermia are thought to be a further source for pulmonary dysfunction (Talay et al, 2011). Hence, based on this information, it is not unexpected that the type of cardiac surgical procedure was not found to differ for those patients who developed PPC's.

Furthermore, the relevance of the findings from Hulzebos et al (2003) are pertinent for comparison, who reported age >70 years, history of smoking, productive cough and diabetes mellitus to be factors that predispose patients to the development of PPC's. The findings of this project, in terms of patient characteristics do not support that of Hulzebos et al (2003).

However, regrettably, the various types of PPC's, for example pneumonia, atelectasis, respiratory failure etc. were not classified in this evaluation. As previously acknowledged, this, together with the discrepancy that exists within the definition of PPC's within the literature, makes it difficult to produce valid comparisons and is a limitation of the current project.

Although, a key discovery was the single isolated factor that appeared to influence the development of PPC's is LV function. LV function has been reported to be a predictive factor for adverse postoperative respiratory outcome, including PMV (Spivack et al, 1996), readmission to ITU with respect to respiratory impairment (Vohra et al, 2005), reintubation (Yazdanian et al, 2013), delayed extubation (Naughton et al, 2003) and as a predictor of operative mortality (Rahmanian et al, 2010).

More pertinently, an association between LV function and the development of PPC's has been introduced by Stiller et al (1994) and Weissman (2004). The association between heart failure and pulmonary function was further evaluated by Snashall and Chung (1991), Johnson et al (2001) and Kortekaas et al, (2012), which confirmed that all patients with chronic heart failure (EF >30%) had reduced lung volumes, specifically total lung capacity, vital capacity, expiratory flow, and airway narrowing, This may predispose patients to the development of PPC's and support the results from this evaluation. From a clinical assessment viewpoint, patients with reduced LV function often present as weak following surgery and are easily fatigued directly as a result of their low cardiac output status (Weissman, 2000). This, in turn puts them at greater risk of PPC's as this is often accompanied by reduced mobility and reduced participation in physiotherapy treatments. However, a contradiction to this finding is the work of Bastos et al (2011) which demonstrated that LV function was not found to be associated with increasing rates of PPC's. The prospect of offering clinical recommendations centred upon LV function will be discussed further in this chapter.

6.3 Limitations

This project has some limitations. It is important to acknowledge that this programme of research was undertaken at a single institution and that the guidelines and protocols used within this centre may differ to other settings.

Data collection for this project was retrospectively extrapolated from the Cardiac Patient Administration System and medical notes. These are based upon subjective and objective assessments from a number of different medical practitioners, which is standard clinical practice and therefore not able to be controlled in a retrospective evaluation. Consequently, due to the subjective nature of documenting a patient's preoperative assessment, discrepancies could exist between patient records, therefore the reliability of the documentation could be questioned. It could be argued that prospective data collection, incorporating a proforma to define and structure the data collection would have been an alternative method to this.

As previously mentioned, pulmonary complications were not classified further into categories of atelectasis and pneumonia, for example. Therefore, there is only a generic interpretation of PPC results. If the result could have been categorised further, it would have facilitated an improved comparison to previous studies and would have added more in the overall context of research into PPCs following cardiac surgery.

Additionally, the results of the statistical analysis of this project has alluded to a possible relationship between reduced LV function and an increased risk for the development of PPCs. It could be questioned as to whether or not, a follow on from the data analysis, incorporating a more sophisticated statistical test i.e. multivariate regression, would have confirmed this. However, the findings from this study could be used a platform to shape future research into this area.

Furthermore, there was no follow-up of patients, therefore any impact on longer term outcomes were not assessed. However, the recommendations for future studies could consider a follow up period, perhaps of 1-month or 3-months postoperatively, as evident in previous studies, so that the impact over a longitudinal period could be evaluated. Although the limitations to the programme are recognised and the potential opportunities to resolve these issues in future studies have been put forward, it is hoped that this work can generate future direction of research into this area.

6.4 Future research

A principal aim for this project was to utilise the information gained in the understanding of PPC's following cardiac surgery so as to inform physiotherapy practice. As previously identified, the literature surrounding physiotherapy clinical practice to reduce the incidence of PPC's, lacked a clearly defined, primary outcome measure. Based on the findings from this thesis, it could now be proposed that LV function could be used as the necessary clearly, defined physiological measure to surround physiotherapy interventions in the future. The results have revealed LV function as a potential physiological screening measure to identify patients at increased risk for the development of PPC's.

Accordingly, it has been identified in the literature that there is a need to provide a more focused approach in the provision of physiotherapy services following cardiac surgery. Although, until this point, it was not known on which group of patients to focus. To address this distinct population of patients, i.e. those with reduced LV function, physiotherapy based initiatives that would centre upon LV function could now be introduced. Therefore, in order to identify those patients at greater risk for the development of PPC's, rather than screening for the various risk factors as initially perceived, it is now recommended to screen patients for their LV function. Based on this, it is proposed that for patients with reduced LV function, i.e. 'moderate' or 'poor', a more integrated, targeted, optimally timed, intensive physiotherapy regime can be provided.

Therefore the findings of this project has now challenged the physiotherapy service protocols as a whole. The potentials for providing a more optimally timed and patient focused treatment programme could be delivered preoperatively and better utilise the time from identification of the patient, to surgery. This will create an optimal timeframe to provide physiotherapy treatment for those patients with reduced LV function that could maximally benefit from this input prior to their surgical procedure.

It could be argued that those individuals with reduced LV function are the 'sicker' patients, those with heart failure and its associated co-morbidities whom would not likely undergo their surgery as elective candidates. They are usually already within the hospital and therefore undergo their surgery on an urgent in-house basis. Subsequently, this supports this view as an optimal timeframe to introduce an intensive preoperative physiotherapy regime. Therefore a recommendation can be offered to investigate the provision of physiotherapy treatment during the preoperative period for patients with reduced LV function.

Although the physiotherapy research included in the narrative review (Chapter 3.0) has examined the various protocols for providing CPT including breathing exercises and IS for patients following cardiac surgery (Stiller et al, 1994; Johnson et al, 1996; Crowe and Bradley, 1997; Brasher et al, 2003; Dias et al, 2010; Urell et al, 2011). The results of these studies were largely based upon postoperative treatment and were found not to influence clinical outcome. However, as acknowledge in the work of Stiller et al (1994), some patients in this study developed PPC's within 12 hours of their surgery, and this brought about the questioning of the optimal timing of the provision of CPT. Subsequently, this finding reinforced the clinical relevance to investigate the impact of CPT during the immediate postoperative period. Those studies conducted by Eales et al (1995) and Patman et al (2001) has provided evidence on the effects of CPT during the period of mechanical ventilation following surgery, however were provided to all routine patients following their surgery during this time and were not targeted to those patients thought to be at greatest risk for the development of PPC's.

Therefore this research has indicated a need to investigate the delivery of CPT during this crucial immediate postoperative period as another prospect for research to be conducted in this area. Potentially, if targeted to the correctly identified individuals, i.e. those with reduced LV function, this may have a positive influence over clinical outcome. With this in mind, an alternative recommendation to the preoperative timeframe would be to assess patients during the immediate postoperative period, based on the screening of their LV function. It may be worthwhile to investigate the provision of an 'early intervention' physiotherapy treatment during the initial period of mechanical ventilation, with the potential to prevent adverse postoperative respiratory outcome. Based on the findings of this work, there is a unique opportunity for physiotherapy based intervention to be introduced at an earlier point in the patient's journey, which has generated new research prospects for physiotherapy and the cardiothoracic service as a whole.

Based on these models of recommendation, a reorganisation of the investment in physiotherapy services is required. In a challenging financial climate in which the NHS finds itself, with the continual demand for cost effective healthcare, it is necessary to consider the financial implications of these proposals. Both models could either be provided in addition to the current physiotherapy practice, which would require a significant increase in resources and would be a more labour intensive strategy, as previously debated by Johnson et al (1996). Alternatively, these concepts could be utilised to call for a more focused physiotherapy intervention and redistribute the current resources to facilitate this. The physiotherapy clinical practice surveys conducted by Tucker et al (1996), Reeve and Ewan (2005) and Overend et al (2010) as outlined in the introductory chapter have all identified a rationale to highlight patients deemed 'high risk' for the development of PPCs preoperatively, to direct the selection of the appropriate patients accordingly. This is in agreement with the findings of this project. Thus, there appears to be a shift in focus within the profession of respiratory physiotherapy, moving away from historical practice and traditional protocols providing prophylactic physiotherapy to all patients following routine cardiac surgery, as initially challenged by Stiller et al (1994).

Additionally, it could be argued that these initiatives encapsulate the role of the physiotherapist as formerly identified in the government strategies for healthcare (Chapter 1.6). By identifying those patients at greater risk for the development of PPC's, has the opportunity to maximise a patients respiratory potential, in addition to facilitating weaning from ventilation and the avoidance of reintubation. These are the key responsibilities of a physiotherapist working in an ICU (WAG, 2006). The recommendations proposed in this project are thought to fulfill the requirement of the 'A Therapy Service Strategy for Wales' (WAG, 2006) with the promotion of early intervention strategies to facilitate the rate of recovery and the avoidance of the development of chronic conditions.

It is hoped that the recommendations and conclusions of this programme of research, as discussed within this thesis, may have the potential to reduce the incidence of PPC's following cardiac surgery and gain a positive influence over clinical outcomes. The recommendations offered could inform future research into utilising LV function as an objective measure and inform change within physiotherapy practice by potentially identifying individuals at risk of developing PPC's based on their LV function. In consideration of this, the wider impact of these findings should now be considered.

The proposed strategies possibly aimed at reducing the incidence of PPC's also have the potential to impact on longer term outcomes, for example, the avoidance of the development of chronic conditions, including PMV and the prevention of deterioration including reintubation and readmission to ITU. This could have a substantial impact on service delivery. These outcomes have been found to be associated with an increased risk of morbidity and mortality and the development of nosocomial infections, as identified in the literature (Kollef, 1993; Fagon, 1996; Kollef et al, 1997; Canver et al, 2003; Pappalardo et al, 2004). Therefore, with consideration of the recommendations, the clinical relevance of the project findings has the potential to have a considerable impact on clinical services currently at ABMU Cardiac Centre.

Furthermore, for the patient, these concepts could result in a faster recovery from surgery and an accelerated discharge home with an improved overall health and well-being and QOL for the patient and their family engaging in their community following cardiac surgery.

From a clinical service perspective, these initiatives would hope to reduced LOS in CITU and thus reduce 'bed blocking', providing the necessary infrastructure to undertake more vital tertiary cardiac services for the community. Thus, generating a more efficient service improvement and delivery which would not only have considerable economic implications but also would impact on the quality of care delivered.

In the future, the concepts discussed could also be utilised not only within physiotherapy but as a clinical decision making tool in addition to risk stratification measures, to decide if patients are suitable candidates for surgery. If patients with reduced LV are found to be associated with adverse outcome, it may be necessary for a consultant surgeon to consider this risk and to delay surgery to allow increased intensive physiotherapy to improve a patient's physical status and strength. Therefore, the findings have the potential to not only inform physiotherapy practice but to also to influence the decision making for other disciplines with the multi-disciplinary team. It is crucial to acknowledge the clinical relevance of this research and how the concepts discussed could be have a direct impact and application to the cardiac surgical service as a whole.

The components of this thesis have produced the literature and supporting clinical data to deliver the aim of understanding the nature and causal factors of PPC's following cardiac surgery. Emerging from this project, physiotherapy services within cardiothoracic surgery have been offered recommendations to facilitate the optimal management for patients that will be identified as high risk for PPC's in the future.

7.0 Conclusion

This research project set out to explore the nature and identifiable causal factors of postoperative pulmonary complications following adult cardiac surgery, so as to inform physiotherapy practice for patients identified as high risk. Further to this, the component chapters also sought to establish the incidence and trends for PPC's, together with determining the effect this complication has on the service performance as a whole. Additionally, it was important to examine the profile of patients that presented for cardiac surgery within the literature and at the local centre, to ascertain if specific preoperative characteristics could have a bearing on PPC's. Moreover, with this knowledge at hand, the physiotherapy service could then be better informed so as to consider developments that could be introduced in an attempt to lessen PPC's following cardiac surgery.

The theoretical literature on preoperative characteristics yielded from the systematic review and the critical appraisal of high quality articles relating to risk factors for the development of PPC's, put forward several characteristics including age, gender, COPD, smoking, and LV function, as possible influential factors. Additionally, the narrative review examined the evidence regarding morbidity and mortality following cardiac surgery, so as to consider PPC's in the broader context and the role of physiotherapy in managing PPC's. The literature chapters provided the necessary evidence base from which the nature and identifiable causal factors of PPC's have been understood. Although, from the main findings of the theoretical evidence emerged an existing theory or understanding of the potential predictive factors for PPC's prior to the service evaluation of cardiac services being undertaken.

The service evaluation conducted at ABMU Cardiac Centre yielded a wealth of information relating to the profile of patients undergoing cardiac surgery together with clinical data and service outcomes. PPC's in this service evaluation were found to be consistent over the study period, affecting 20% of the cardiac surgical population. Recently, the risk adjusted mortality rate for cardiac surgery at the ABMU cardiac centre is 2.02% (SCTS, 2013). Although this figure appears low, the service evaluation has verified the clinical opinion and observation from the outset. It was perceived that the local cardiac surgical population is older and frailer and potentially the development of PPC's could have an impact on the in-hospital mortality rate following adult cardiac surgery. For one fifth of all patients undergoing cardiac surgery, the development of PPC's has been shown to call for a significantly prolonged length of stay in ICU and can increase the overall hospital stay by as much as three-fold. From a service perspective, PPC's call for a considerable utilisation of resources which has a significant impact on the cardiac surgical service including hampering the levels of surgical activity.

On further examination of the patient profile, LV function was identified as the only preoperative characteristic to be associated with the development of PPC's. This association is consistent with that proposed by Johnson et al (2001) who presented an association between worsening pulmonary function and reduced LV function, however, this is contradictory to the work of Bastos et al (2011). This finding of a single characteristic as a predisposing factor was unexpected and changed the pre-existing understanding that had emerged following the literature reviews, as other patient characteristics that were highlighted as influential factors did not appear to be prevalent.

The findings of this research are extremely relevant to clinical practice today as prior to this research, the physiotherapy practice within cardiothoracic surgery at ABMU had not been challenged. Specifically, in utilising LV function as an objective measure in physiotherapy led preoperative screening programme to identify those patients at greater risk for the development of PPC's, could potentially have policy implications for physiotherapy practice following cardiac surgery. From a clinical perspective, the findings and recommendations from this research may have a direct effect on clinical practice in this field of study in the future.

Secondly, the main findings have given emphasis to the prudent need of employing strategies to manage PPC's and where possible improve clinical outcomes. Therefore this work has postulated the potential benefit of a physiotherapy led clinical intervention to address PPS's that could improve the clinical outcomes of patients and provide prospective benefits for service provision. Although LV function as a screening measure has not been investigated for its use as a predictive strategy in this project, its recommendation would be considerably worthwhile for investigation in the near future. A potential would be to investigate the feasibility of developing a screening tool based on a patients LV function, to predict patients at greater risk for the development of PPC's. The supportive information and clinical data from this research could be used as a foundation to inform these developments in future research.

Therefore, this research project has been undertaken and reviewed against the aim and objectives as outlined in Chapter 1 and from its conclusions, it is pertinent to note that these aims and objectives have been completed. This programme has contributed to the research previously conducted and has aided the progression of knowledge in this field and perhaps has influenced further understanding on this subject. The future research has been presented so that this additional work would be able to inform developments that would have the potential to have a bearing and application on the entire cardiac surgical service, locally and nationally. This demonstrates the overall significance of this work and emphasizes how this work could be invaluable to the cardiothoracic field in the future.

Bibliography

Abertawe Bro Morgannwg University Health Board (2012) *Welcome to the Cardiac Centre.* [Online] Available from: http://www.swansea-tr.wales.nhs.uk/cardiac/. [Accessed: 7th February 2013].

Adabag, A. Wassif, H. Rice, K. Mithani, S. Johnson, D. Bonawitz-Conlin, J. Ward, H. McFalls, E. Kuskowski, M & Kelly, R. (2010) Preoperative pulmonary function and mortality after cardiac surgery. *American Heart Journal.* 159. p.691-697.

Adair, N. & Kon, N. (1994) Respiratory Complications in Cardiac Surgery. *Clinical Pulmonary Medicine.* 1 (5). p.301-312.

Al-Alao, B. Parissis, H. McGovern, E. Tolan, M & Young, V. (2012) Propensity analysis of outcome in coronary artery bypass graft surgery patients >75 years old. *General Thoracic and Cardiovascular Surgery.* 60. p.217-224

Albu, G. Babik, B. Késmàrky, K. Balàzs, M. Hantos, Z & Petàk, F. (2010) Changes in Airway and Respiratory Tissue Mechanics After Cardiac Surgery. *Annals of Thoracic Surgery.* 89. p.1218-1216

American Heart Association (2012). *Types of Heart Failure.* [Online] Available From: http://www.heart.org/HEARTORG/Conditions/HeartFailure/AboutHeartFailure/Types-of-HeartFailure_UCM_306323_Article.jsp. [Accessed: 1st November, 2013]

Anderson RJ, O'Brien M, MaWhinney S. VillaNueva, C. Moritz, T. Sethi, G. Henderson, W. Hammermeister, K. Grover, F. Shroyer, A. (1999) Renal failure predisposes patients to adverse outcome after coronary artery bypass surgery. *Kidney International.* 55. p.1057-1062.

Andrejaitiene, J. Sirvinskas, E. & Bolys, R (2004) The influence of cardiopulmonary bypass on respiratory dysfunction in early postoperative period. *Medicina.* 40 (1). p.7-12.

Al-Sarraf, N. Thalib, L. Hughes, A. Tolan, M. Young, V. & McGovern, E. (2008) Effect of Smoking on Short-Term Outcome of Patients Undergoing Coronary Artery Bypass Surgery. *The Annals of Thoracic Surgery.* 86. p.57-523.

Arom, K. Emery, R. Petersen, R. & Schwartz, M. Cost-Effectiveness and Predictors of Early Extubation (1995) *Annals of Thoracic Surgery.* 60 p.127-132.

Ashraf, M. Mortasawi, A. Grayson, A & Oo, A. Effect of Smoking Status on Mortality and Morbidity Following Coronary Artery Bypass Surgery (2004) *The Journal of Thoracic and Cardiovascular Surgery.* 52. p.268-273.

Audit Commission. (1999) Critical to Success. *The place of efficient and effective critical care services within the acute hospital.* Oxon: Audit Commission Publications.

Babik, B. Asztalos, T. Petàk, F. Deàk, Z. & Hantos, Z. (2003) Changes in Respiratory Mechanics During Cardiac Surgery. *Anaesthesia & Analgesia.* 96. p.1280-1287.

Bando, K. Sun, K. Binford, R. & Sharp. T. (1997) Determinants of Longer Duration of Endotracheal Intubation After Adult Cardiac Operations. *The Annals of Thoracic Surgery.* 63. p.1026-1033.

Bardell, T. Legare, J. Buth, K. Hirsch, G. & Ali, I. (2003) ICU readmission after cardiac surgery. *European Journal of Cardiothoracic surgery.* 23. p.354-359.

Bastos, T. De Melo, V. Silveira, F. & Guerra, D. (2011) Influence of respiratory muscle strength in evolution of patients with heart failure after cardiac surgery. *Revista Brasileira de Cirurgia Cardiovascular.* 26 (3). p.355-363.

Bevelaqua, F. Garritan, S. Haas, F. Salazar-Schicchi, J. Axen, K. & Reggiani, J. (1990) Complications after cardiac operations in patients with severe pulmonary impairment. *The Annals of Thoracic Surgery*. 50 (4). p.602-606.

Bhatti, F. Grayson, A. Grotte, G. Fabri, B. Au, J. & Bridgewater, B. (2006) The logistic EuroSCORE in cardiac surgery: how well does it predict operative risk?. *Heart.* 92 (12). p.1817-1820.

Brasher, P. McClellan, K. Denehy, L. & Story, I. (2003) Does removal of deep breathing exercises from a physiotherapy program including pre-operative education and early mobilisation after cardiac surgery alter patient outcomes? *Australian Journal of Physiotherapy.* 49. p.165-173

Bridgewater, B. (2009) National Clinical Audit: Lessons From Cardiac Surgery. *Royal College of Surgeons of England. 91. p. 296-297.*

Bridgewater, B. (2011) Outcomes: The Battle For Hearts and Minds. *Royal College of Surgeons of England. 93. p.238-239.*

Bridgewater, B. Keogh, B. Kinsman, R. & Walton, P. (2008) *Sixth National Adult Cardiac Surgical Database Report*. Oxford: Dendrite Clinical Systems Ltd.

British Heart Foundation (2012) *Coronary Heart Disease Statistics* [Online]. Available from: http://www.bhf.org.uk/publications/view-publication.aspx [Accessed: 30th September, 2013].

Brophy, S. Snooks, H. and Griffiths, L. (2008) *Small-Scale Evaluations in Health – A Practical Guide.* Los Angeles: SAGE Publications Ltd.

Campeau, L. (1976) Grading of Angina Pectoris. *Circulation.* 54. p. 522-523.

Canver CC & Chanda J (2003) Intraoperative and Postoperative Risk Factors for Respiratory Failure After Cardiac Surgery. *The Annals of Thoracic Surgery*. 75. p.853-858.

Canver, C. Nichols, R. Kroncke, G. (1998) Influence of Age-Specific Lung Function on Survival After Coronary Bypass. *The Annals of Thoracic Surgery. 66. p.144-147.*

Cheng, D. Karski, J. Peniston, C. Raveendran, G. Asokumar, B. Carroll, J. Tirone, D. Sandler, A. (1996) Early Tracheal Extubation after Coronary Artery Bypass Graft Surgery Reduces Costs and Improves Resource Use: A Prospective, Randomized, Controlled Trial. *The Journal of the American Society of Anesthesiologists.* 85 (6). p. 1300-1310.

Christakis, G.T. Fremes, S.E. Naylor, C.D. Chen, E. Rao, V. Goldman, B.S. (1996) Impact of preoperative risk and perioperative morbidity on ICU stay following coronary artery bypass surgery. *Cardiovascular Surgery*. 4 (1). p.29-35.

Chonchol, M.B. Aboyans, V. Lacroix, P. Smits, G. Berl, T. & Laskar, M. (2007) Long-term outcomes after coronary artery bypass grafting: Preoperative kidney function is prognostic. *The Journal of Thoracic and Cardiovascular Surgery*. 134(3) p.683-689.

Cohen, A. Katz, M. Katz, R. Hauptman, E. Schachner, A. (1995) Chronic Obstructive Pulmonary Disease in Patients Undergoing Coronary Artery Bypass Grafting. *The Journal of Thoracic and Cardiovascular Surgery*. 109 (3). p. 574-581.

Cornelissen, H. & Arrowsmith, J. (2006) Preoperative assessment for cardiac surgery. *Continuing Education in Anaesthesia, Critical Care & Pain.* 6 (3). p.109-113.

Cox, C. Ascione, R. Cohen, A. Davies, I. Ryder, I. Angelini, G. (2000) Effect of Cardiopulmonary Bypass on Pulmonary Gas Exchange: A Prospective Randomized Study. *The Annals of Thoracic Surgery*. 69. p. 140-145.

Crawford, M.H. DiMarco, J.P and Paulus, W.J. (2010). *Cardiology.* 3rd Edition. Philadelphia: Elsevier.

Critical Appraisal Skills Programme, (2010), *Critical Appraisal Skills Programme: making sense of evidence about clinical effectiveness: 11 questions to help you make sense of a clinical trial. [Online] Available from:* http://www.casp-uk.net/wp content/uploads/2001/11/CASP_RCT_Appraisal_Checklist_14oct10.pdf. [Accessed: 7th June, 2013].

Crowe, J. & Bradley, C. (1995) The Effectiveness of Incentive Spirometry With Physical Therapy for High-Risk Patients After Coronary Artery Bypass Surgery. *Physical Therapy.* 77 (3) p. 260-268.

Chartered Society of Physiotherapy (2013) *Criteria: Physiotherapy management and treatment* [Online] Available from: http://www.csp.org.uk/professional-union/professionalism/csp-expectations-members/quality-assurance-standards/section-8-0. [Accessed: 24th October, 2013].

CONSORT (2010) *CONSORT – Transparent Reporting of Trials* [Online] Available from: http://www.consort-statement.org [Accessed: 1st June, 2013].

Crook, M.A. (2003) The Caldicott Report and Patient Confidentiality. *Journal of Clinical Pathology.* 56 (6): p. 426-42.

De Morton, N.A. (2009) The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. *Australian Journal of Physiotherapy.* 55(2) p.129-133.

Department of Health (2000) *National Service Framework for Coronary Heart Disease.* [Online] London: Department of Health. Available from:

http://www.gov.uk/goverment/publications/quality-standards-for-coronary-heart-disease-care. [Accessed: 22nd October, 2013].

Dias, C. Vieira, R. Oliveira, J. Lopes, A. Menezes, S. Guimarães, F. (2010) Three physiotherapy protocols: Effect on pulmonary volumes after cardiac surgery. *Jornal brasileiro de pneumologia.* 37 (1). p. 54-60.

Dimopoulou, I. Daganou, M. Tsintzas, K. Tzelepis, G. (1998) Effect of severity of long-standing congestive heart failure on pulmonary function. *Respiratory Medicine.* 92. p. 1321-1325.

Dixon, B. Campbell, D. Santamaria, J. (2008) Elevated pulmonary dead space and coagulation abnormalities suggest lung mircrovascular thrombosis in patients undergoing cardiac surgery. *Intensive Care Medicine.* 34. p. 1216-1223.

Donabedian, A. (1988) The Quality of Care: how can it be assessed? *Journal of the American Medical Association.* 260 p.1743-1748.

Dunstan, J. and Riddle, M. (1997) Rapid recovery management: The effects on the patient who has undergone heart surgery. *Heart & Lung.* 26 (4). p. 289-298.

Dupis, J. (2008) Predicting outcomes in cardiac surgery: risk stratification matters? *Current Opinion in Cardiology.* 23. p. 560-567.

Eales, C. Barker, M. Cubberley, N. (1995) Evaluation of a single chest physiotherapy treatment to post-operative, mechanically ventilated cardiac surgery patients. *Physiotherapy Theory and Practice.* 11. p. 23-28.

Engoren, M. Buderer, N.F. Zacharias, A. Habib, R.H. (1999) Variables Predicting Reintubation After Cardiac Surgical Procedures. *The Annals of Thoracic Surgery.* 67. p. 661-665.

Estenne, M. Yernault, J. Smet, J. Troyer, A. (1985) Phrenic and diaphragm function after coronary artery bypass grafting. *Thorax.* 40. p. 293-299.

EuroSCORE (2003) *EuroSCORE Scoring System.* [Online] Available from: http://www.euroscore.org/logisticeurscore.htm. [Accessed: 1st October, 2013].

Faggian, G. Milano, A.D. Santini, F. Petrilli, G. Pizzuti, M. Galati, M. Franchi, P. Mazzucco, A. (2011) Urgent cardiac surgery in octogenarians. *European Surgery: ACA Acta Chirurgica Austriaca. 43 (2). p. 90-95.*

Fagon, J. Chastre, J. Vuagnat, A. Trouillet, J. (1996) Nosocomial pneumonia and mortality among patients in intensive care units. *The Journal of the American Medical Association.* 275 (11). p. 866-869.

Faritous, Z.S. Aghdale, N. Yazdanian, F. Azarfarin, R. Dabbagh, A. (2011) Perioperative risk factors for prolonged mechanical ventilation and tracheostomy in women undergoing coronary artery bypass graft with cardiopulmonary bypass. *Saudi Journal of Anaesthesia.* 5 (2). p. 1167-1169.

Ferguson, T.B, Hammill, B.G, Peterson, E.D. DeLong, E.R. Grover, F. (2002). A Decade of Change – Risk Profiles and Outcomes for Isolated Coronary Artery Bypass Grafting Procedures, 1990-1999: A Report From the STS National Database Committee and the Duke Clinical Research Institute. *Annals of Thoracic Surgery.* 73. p. 480-490.

Ferrer, M. Bernadich, O. Alarcón, A. Badia, J. R. Torres, A. (2002) Noninvasive Ventilation During Weaning From Mechanical Ventilation. *Clinical Pulmonary Medicine.* 9 (5). p. 279-283.

Filsoufi, F. Rahmanian, P.B. Castillo, J.G. Chikwe, J. Annapoorna, K. Adams, D.H. (2007) Results and Predictors of Early and Late Outcome of Coronary Artery Bypass

Grafting in Patients with Severely Depressed Left Ventricular Function. *Annals of Thoracic Surgery*. 84 (3). p. 808-816.

Filsoufi, F. Rahmanian, P.B. Castillo, J.G. Chikwe, J. Adams, D.H. (2008) Predictors and Early and Late Outcomes of Respiratory Failure in Contemporary Cardiac Surgery. *Chest.* 133 (3). p. 713-721.

Gaynes, R. Bizek, B. Mowry-Hanley, J. Kirsh, M. (1991) Risk Factors for Nosocomial Pneumonia After Coronary Artery Bypass Graft Operations. *Annals of Thoracic Surgery.* 51. p. 215-218.

Geissler, H.J. Hölzl, P. Marohl, S. Kuhn-Régnier, F. Mehlhorn, U. Südkamp, M. de Vivie, E.R. (2000) Risk stratification in heart surgery: comparison of six score systems. *European Journal of Cardiothoracic Surgery.* 17 (4). p. 400-406.

Ghotkar, S.V. Grayson, A.D. Fabri, B.M. Dihmis, W.C. Pullan, D.M. (2006) Preoperative calculation of risk for prolonged intensive care unit stay following coronary artery bypass grafting. *The European Journal of Cardiothoracic Surgery.* 31. p. 1-14.

Habib, R.H. Zacharias, A. Engoren, M. (1996) Determinants of Prolonged Mechanical Ventilation After Coronary Artery Bypass Grafting. *Annals of Thoracic Surgery.* 62. p.1164-1171.

Hawkes, C.A. Dhileepan, S. Foxcroft, D. (2004) Early Tracheal Extubation for Adult Cardiac Surgical Patients. *Cochrane Database of Systematic Reviews 2003.* Issue 4.

Health Quality Improvement Partnership (HQIP) (2011) *A Guide for Clinical Audit, Research and Service Review – An educational toolkit designed to help staff differentiate between clinical audit, research and service review activities.* [Online]. Available from: http://www.hqip.org.uk/assets/downloads/audit-research-service-evaluation.pdf. [Accessed: 30th December, 2013].

Higgins, T.L. Estafanous, F.G. Loop, F.D. Beck, G.J. Blum, J.M, Paranandi, L. (1992) Stratification of morbidity and mortality outcome by preoperative risk factors in coronary artery bypass patients. *JAMA*. 267. p. 2344.

Hulzebos, E.H.J. Van Meeteren, N.L. De Bie, R.A. Dagnelie, P.C. Helders, P.J.M. (2003) Prediction of Postoperative Pulmonary Complications on the Basis of Preoperative Risk Factors in Patients Who Had Undergone Coronary Artery Bypass Graft Surgery. *Physical Therapy*. 83 (1). p.8-16.

Hulzebos, E.H.J. Helders, P.J.M. Favié, N.J. De Bie, R.A. De La Riviere, A.B. Van Meeteren, N.L. (2006) Preoperative Intensive Inspiratory Muscle Training to Prevent Postoperative Pulmonary Complications in High-Risk Patients Undergoing CABG Surgery: A Randomized Control Trial. *JAMA*. 296 (15). p.1851-1857.

Hulzebos, E.H.J. Smir, Y. Helders, P.P.J.M. Van Meeteren, N.L.U. (2012) Preoperative physical therapy for elective cardiac surgery patients. *Cochrane Database of Systematic Reviews 2012*. Issue 11.

Johnson, D. Hurst, T. Thomson, D. Mycyk, T. Burbridge, B. To. T. Mayers, I. (1996) Respiratory Function After Cardiac Surgery. *Journal of Cardiothoracic and Vascular Anesthesia.* 10 (5). p. 57-577.

Johnson, D. Kelm, C. Thomson, D. Burbridge, B. Mayers, I. (1996) The Effect of Physical Therapy on Respiratory Complications Following Cardiac Valve Surgery. *Chest.* 109. p. 638-644.

Johnson, D. Thomson, D. Mycyk, T. Burbridge, B. Mayers, I. Respiratory Outcomes with Early Extubation After Coronary Artery Bypass Surgery. *Journal of Cardiothoracic and Vascular Anesthesia.* 11(4). p.474-480.

Johnson, B.D. Beck, K.C. Olson, L.J. O'Malley, K.A. Allison, T.G. Squires, R.W. Gau, G. T. (2001). Pulmonary Function in Patients With Reduced Left Ventricular Function Influence of Smoking and Cardiac Surgery. *Chest.* 120. p.1869-1876.

Johnson, R.G. Arozullah, A.M. Neumayer, L. Henderson, W.G. Hosokawa, P. Khuri, S.F. (2007) Multivariable Predictors of Postoperative Respiratory Failure after General and Vascular Surgery: Results from the Patient Safety in Surgery Study. *Journal of the American College of Surgeons. 204 (6). p. 1188-1198.*

Jones, R. Nyawo, B. Jamieson, S. Clark, S. (2011) Current smoking predicts increased operative mortality and morbidity after cardiac surgery in the elderly. *Interactive Cardiovascular and Thoracic Surgery.* 12. p. 449-453.

Kacila, M. Tiwari, K. K. Gravnov, N. Omerbasic, E. Śtraus, S. (2010) Assessment of the Initial and Modified Parsonnet Score in Mortality Prediction of the Patients Operated in the Sarajevo Heart Centre. *Bosnian Journal of Basic Medical Sciences.* 10 (2) p.165-168.

Kemp, C.D. and Conte, J.V. (2012) The pathophysiology of heart failure. *Cardiovascular Pathology.* 21 (5). p. 365-371.

Keogh, B.E. and Kinsman, R. (2004) *Fifth National Adult Cardiac Surgical Database Report 2003.* Oxford: Dendrite Clinical Systems Ltd.

Kerendi, F. Halkos, M.E. Puskas, J.D. Lattouf, O.M. Kilgo, P. Guyton, R.A. Thourani, V.H. (2011) Impact of Off-Pump Coronary Artery Bypass Graft Surgery on Postoperative Pulmonary Complications in Patients With Chronic Lung Disease. *Annals of Thoracic Surgery.* 91 p. 8-15.

Klein, A. Vuylsteke, A. and Nashef, S. (2008) *Core Topics in Cardiothoracic Critical Care.* Cambridge: Cambridge University Press.

Kollef, M.H. (1993) Ventilator-Associated Pneumonia: a multivariate analysis. *JAMA.* 270 p. 1965-1970.

Kollef, M.H. Wragge, T. Pasque, C. (1995) Determinants of Mortality and Multiorgan Dysfunction in Cardiac Surgery Patients Requiring Prolonged Mechanical Ventilation. Chest. 107 p.1395-1401.

Kollef, M.H. Sharpless, L. Vlasnik, J. Pasque, C. Murphy, D. Fraser, V.J. (1997) The Impact of Nosocomial Infections on Patient Outcomes Following Cardiac Surgery. *Chest.* 112. p. 666-675.

Kortekaas, K.A. Lindeman, J.H.N. Verteegh, M.I.M. Stijnen, T. Dion, R.A.E. Klautz, R.J.M. (2012) Preexisting heart failure is an underestimated risk factors in cardiac surgery. *Netherlands Heart Journal.* 20. p. 202-207.

Kristjànsdóttir, A. Ragnarsdóttir, M. Hannesson, P. Beck, H.J. Torfason, B. (2004) Respiratory movements are altered three months and one year following cardiac surgery. *Scandinavian Cardiovascular Journal.* 38 p. 98-103.

Kroenke, K. Lawrence, V.A. Theroux, J.F. Tuley, M.R. Hilsenbeck, S. (1993) Postoperative complications after thoracic and major abdominal surgery in patients with and without obstructive lung disease. *Chest.* 104 (5) p. 1445-1451.

Laizo, A. Delgado, F.E. Rocha, G.M. (2010) Complications that increase the time of hospitalisation at ICU of patients submitted to cardiac surgery. *Revista Brasileira de Cirurgia Cardiovascular. 25 (2) p. 166-171.*

Leal-Noval, S.R. Marquez-Vàcaro, J.A. Garcià-Curiel, A. Camacho-Larana, R. et al (2000) Nosocomial pneumonia in patients undergoing heart surgery. *Critical Care Medicine.* 28 (4) p. 935-940.

Litmathe, J. Kurt, M. Feindt, P. Garns, E. Boeken, U. (2009) Predictors and Outcome of ICU Readmission after Cardiac Surgery. *Thoracic and Cardiovascular Surgery.* 57 (7) p.391-394.

LoCicerio, J. McCann, B. Massad, M. Joob, A. (1992) Prolonged ventilatory support after open-heart surgery. *Critical Care Medicine.* 20 (7) p.990-992.

Lola, I. Levidiotou, S. Petrou, A. Arnaoutoglou, H. Apostolakis, E. Papadopoulos, G.S. (2011) Are there independent predisposing factors for postoperative infections following open heart surgery? *Journal of Cardiothoracic Surgery.* 6 p. 151-160.

London, M.D. Shroyer, A.L. Jernigan, V. (1996) "Fast" vs. "Slow" Track: Factors Influencing Early Extubation and Length of Stay. *Anesthesiology.* 85 (3A) A127.

McDonald, K.M. Sundaram, V. Bravata, D.M et al (2007) Conceptual Frameworks and their application to evaluating care coordination interventions. In: *Closing the Quality Gap: A Critical Analysis of Quality Improvement Strategies.* Rockville: Agency for Healthcare Research and Quality. Chapter 5. [Online] Available from: http://www.ncbi.nlm.nih.gov/books/NBIC44008/ [Accessed: 24th January, 2014].

Maria, R. Mazzoni, M. Parolini, M. Gregori, D. Bortone, F. Arena, V. Parodi, O. (2005) Predictive value of EuroSCORE on long term outcome in cardiac surgery patients: a single institution study. *Heart.* 91. p. 779-784.

Matsumoto, M. Konishi, Y. Miwa, S. Minakata, K. (1997) Effect of Different Methods of Internal Thoracic Artery Harvest on Pulmonary Function. *Annals of Thoracic Surgery.* 63 p. 653-655.

Maxwell, R.J. (1984) Prospectus in NHS management: quality assessment in health. *BMJ.* 288 p.148-172.

Michalopoulos, A. Geroulanos, S. Papadimitriou, L. Papadakis, E. Triantafillou, K. Papadopoulous, K. Palatianos, G. (2001) Mild or Moderate Chronic Obstructive Pulmonary Disease Risk in Elective Coronary Artery Bypass Grafting Surgery. *World Journal of Surgery*. 25 p.1507-1511.

Michalopolous, A. Geroulanos, S. Rosmarakis, E.S. Falagas, M.E. (2006) Frequency, characteristics, and predictors of microbiologically documented nosocomial infections after cardiac surgery. *European Journal of Cardiothoracic Surgery*. 29 p. 456-460.

Miranda, R.C. Padulla, S.A.T. Bortolatto, C.R. (2011) Respiratory physiotherapy and its application in preoperative period of cardiac surgery. *Revista Brasileira de Cirurgia - Cardiovascular*. 26 (4) p. 647-652.

Moorjani, N. Voila, N. and Ohri, S. (2011) *Key questions in cardiac surgery*. Shrewsbury: TFM Publishing.

Moulton, M.J. Creswell, L.L. Mackey, M.E. Cox, J.L. Rosenbloom, M. (1996) Obesity is not a risk factor for significant adverse outcomes after cardiac surgery. *Circulation*. 94 (9) 87-92.

Murthy, S.C. Arroliga, A.C. Walts, P.A. Feng, J. Yared, J. Lytle, B.W. Blackstone, E.H. (2007) Ventilatory dependency after cardiovascular surgery. *The Journal of Thoracic and Cardiovascular Surgery*. 134 (2) p. 484-90.

Nashef, S.A.M. Roques, F. Michel, P. Gauducheau, E. Lemeshow, S. Salamon, E. (1999) European system for cardiac operative risk evaluation (EuroSCORE). *European Journal of Cardiothoracic Surgery*. 16 p.9-13.

Nashef, S.A.M. Roques, F. Hammill, B.G. Peterson, E.D. Michel, P. Grover, F.L. Wyse, R.K.H. Ferguson, B. (1999) Validation of European System for Cardiac Operative Risk

Evaluation (EuroSCORE) in North American Cardiac Surgery. *European Journal of Cardiothoracic Surgery.* 22 p. 101-105.

National Patient Safety (2009) *National Patient Safety Agency, National Research Ethics Service - Defining Research.* [Online] Available from http://www.nres.npsa.nhs.uk. [Accessed January 11th, 2010].

National Institute for Cardiovascular Outcomes Research (NICOR), (2011) *National Adult Cardiac Surgery Audit – Annual Report 2010-2011.* [Online] Available from: http://www.ulc.ac.uk/nicor/audits/adultcardiacsurgery [Accessed: 11th July, 2013].

Naughton, C. Cheek, L. O'Hara, K. (2005) Rapid recovery following cardiac surgery: a nursing perspective. *British Journal of Nursing.* 14 (4) p. 214-219.

Naughton, C. Reilly, N. Powroznyk, A. Aps, C. Hunt, T. Hunter, D. Parsons, R.S. Sherry, Spakman, D. Wielogorski, A. Fenek, R.O. (2003) Factors determining the duration of tracheal intubation in cardiac surgery: a single-centre sequential patient audit. *European Journal of Anesthesiology. 20 p. 225-233.*

Ng, C.S.H. Wan, S. Yim, A.P.C. Arifi, A. A. (2002) Pulmonary Dysfunction After Cardiac Surgery. *Chest.* 121 p. 1269-1277.

Ngaage, D.L. Martins, E. Orkell, E. Griffin, S. Cale, A.R.J. Cowen, M.E. Guvendik, L. (2002) The impact of the duration of mechanical ventilation on the respiratory outcome in smokers undergoing cardiac surgery. *Cardiovascular Surgery.* 10 (4) p. 34-350.

O'Donohue, W.J. (1992) Postoperative Pulmonary Complications. *Postgraduate Medicine.* 91 p.167-175.

Overend, T.J. Anderson, M. Jackson, J. Lucy, S.D. Prendergast, M. Sinclair, S. (2010) Physical Therapy Management for Adult Patients Undergoing Cardiac Surgery: A Canadian Practice Survey. *Physiotherapy Canada.* 62 p.215-221.

Ovretveit, J. (1998) *Evaluating Health Interventions.* Buckingham: Open University Press.

Palfrey, C. Thomas, P. and Phillips. C. (2012) *Evaluation for the Real World. The Impact of Evidence in Policy Making.* Bristol: The Policy Press.

Paone, G. Higgins, R. Havstad, S.L. Silverman, N. (1998) Does Age Limit the Effectiveness of Clinical Pathways After Coronary Artery Bypass Graft Surgery? *Circulation.* 98 (195) p. 4111-4511.

Pappalardo, F. Franco, A. Landoni, G. Cardano, P. Zangrillo, A. Alferi, O. (2004) Long-term outcome and quality of life of patients requiring prolonged mechanical ventilation after cardiac surgery. *European Journal of Cardio-thoracic Surgery.*25. p.548-552.

Parsonnet, V. Dean, D. Berstein, A.D. (1989). A Method of Uniform Stratification of Risk for Evaluating the Results of Surgery in Acquired Adult Heart Disease. *Circulation.* 79 (1) p.3-12.

Pasquina, P. Tramér, M.R. Walder, B. (2003) Prophylactic Respiratory Physiotherapy after Cardiac Surgery: systematic review. *BMJ.* 327 (7428):1379-1384.

Patman, S. Sanderson, D. Blackmore, M. (2001) Physiotherapy following cardiac surgery: Is it necessary during the intubation period? *Australian Journal of Physiotherapy.* 47 p.7-16.

PEDro (1999) *PEDro- Physiotherapy Evidence Database.* [Online] Available from: http://www.pedro.org.au [Accessed: 1st June, 2013].

Pignay-Demaria, V. Lespérance, F. Demaria, R.G. (2003) Depression and anxiety and outcomes of coronary artery bypass surgery. *Annals of Thoracic Surgery.* 75(1) p. 314-321.

Poelaert, J. and Roosens, C. (2009) Prevention of Pulmonary Dysfunction after Cardiac Surgery by a Vital Capacity Maneuver: Is it so simple? *Critical Care Medicine.* 37(2) p.762-763.

PRISMA (2009) *PRISMA Transparent Reporting of Systematic Reviews and Meta-Analyses.* [Online] Available from: http://www.prisma-statement.org [Accessed: 7th April, 2013].

Pryor, J.A (1999) Physiotherapy for airway clearance in adults. *European Respiratory Journal.* 14 p. 1418-1424.

Pryor, J.A and Prasad, S.A (2002) *Physiotherapy for Respiratory and Cardiac Problems. Adults and Paediatrics.* 3rd Edition. London: Churchill Livingstone.

Quizlet (2013) *Alterations in Perfusion.* [Online] Available from: http://quizlet.com/5980108/flashcards [Accessed: 19th November, 2013].

Rady, M.Y. Ryan, T. (1999) Perioperative predictors of extubation failure and the effect on clinical outcome after cardiac surgery. *Critical Care Medicine.* 27(2) p.340-347.

Rady, M.Y. Thomas, R. Starr, N.J. (1997) Early Onset of Acute Pulmonary Dysfunction after Cardiovascular Surgery: Risk Factors and Clinical Outcome. *Critical Care Medicine.* 25 (11) p.1831-1839.

Rahmanian, P.B. Adams, D.H. Castillo, J.G. Carpentier, A. Filsoufi, F. (2010) Predicting Hospital Mortality and Analysis of Long-Term Survival After Major

Noncardiac Complications in Cardiac Surgery Patients. *Annals of Thoracic Surgery.* 90 p.1221-1229.

Rajakaruna, C. Rogers, C.A. Angelini, G.D. Ascione, R. (2005) Risk factors for and economic implications of prolonged ventilation after cardiac surgery. *The Journal of Thoracic and Cardiovascular Surgery.* 130 (5) p.1270-1277.

Rees, M. and Dineschandra, J. (2006) Risk stratification in assessing risk in coronary artery bypass surgery. *Westminster Research.* [Online] Available from: http:///www.wmin.ac.uk/westminsterresearch [Accessed 12th June, 2009].

Reeve, J. and Ewan, S. (2005) The Physiotherapy Management of the Coronary Artery Bypass Graft Patient. *Journal of the Association of Chartered Physiotherapists in Respiratory Care.* 37 p.35-45

Ried, M. Haneya, A. Homann, T. Kolat, P. Schmid, C. Diez, C. (2011) Female Gender and the Risk for Death After Cardiac Surgery in Septuagenarians and Octogenarians: A Retrospective Observational Study. *Gender Medicine.* 8 (4) p. 252-260.

Rodrigues, R.R. Sawada, A.Y. Rouby, J.J. Fukuda, M.J. Neves, F.H. Carmona, M.J. Pelosi, P. Auler, J.O. Malbouisson, L.M.S. (2011) Computed tomography assessment of lung structure in patients undergoing cardiac surgery with cardiopulmonary bypass. *Brazilian Journal of Medical and Biological Research.* 44 p.598-605.

Rodriguez, R. Torrents, A. García, P. Ribera, A. Permanyer, G. Moradi, M. Dousset, P. Igual, A. Murtra, M. (2002) Cardiac surgery in elderly patients. *Revista Espanola de Cardiologica.* 55 (11) p.1159-68.

Rolla, G. Fogliati, P. Bucca, C. Brussino, L. Di Rosa, E. Di Summa, M. Comoglio, C. Malara, D. Ottino, G.M. (1994) Effect of pleurotomy on pulmonary function after coronary artery bypass grafting with internal mammary artery. *Respiratory Medicine.* 88 p.417-420.

Roques, F. Nashef, S.A.M. Michel, P. Gauducheau, E. Vincentiis, C. Baudet, E. Cortina, J. David, M. Faichney, A. Gabrielle, F. et al (1999) Risk factors and outcome in European cardiac surgery: analysis of the EuroSCORE multinational database of 19030 patients. *European Journal of Cardio-thoracic Surgery.* 15 p.816-823.

Roques, F. Michel, P. Goldstone, A.R. Nashef, S.A.M. (2003) The logistic EuroSCORE. *European Heart Journal.* 24 (9) p.881-882.

Rothenhäusler, H. Grieser, B. Nollert, G. (2005) Psychiatric and Psychosocial outcome of cardiac surgery with cardiopulmonary bypass: a prospective 12-month follow-up study. *General Hospital Psychiatry.* 27(1) p.18-28.

Rymaszewska, J. Klejna, A. Hadrys, T. (2003) Depression and anxiety in coronary artery bypass grafting patients. *European Psychiatry.* 18(4) p.155-160.

Saleh, H.Z. Mohan, K. Shaw, M. Al-Rawi, O. Elsayed, H. Walshaw, M. Chalmers, J.A.C. Fabri, B.M. (2012) Impact of chronic obstructive pulmonary disease severity on surgical outcomes in patients undergoing non-emergent coronary artery bypass grafting. *European Journal of Cardio-Thoracic Surgery.* 42 p.108-113.

Samuels, L.E. Kaufman, M.S. Morris, R.J. Promisloff, R. Brockman, S.K. (1998) Coronary Artery Bypass Grafting in Patients With COPD. *Chest.* 113 p.878-882.

Sawatzky, J. and Naimark, B. (2009) Coronary Artery Bypass Graft Surgery: Exploring a Broader Perspective of Risks Outcomes. *The Journal of Cardiovascular Nursing.* 24 (3) p.198-206.

Sawatzky, J. and Naimark, B. (2009) The Coronary artery bypass surgery trajectory: Gender differences revisited. *European Journal of Cardiovascular Nursing.* 8 p. 302-308.

Serag, A.R. and Serag, A.R. (2007) Risk Stratification Analysis of Operative Mortality in Patients Undergoing Mitral Valve Replacement. *Heart Mirror Journal.* 1 (2) p.52-56.

Sheppard, M. (2012) Complications following cardiac coronary artery bypass surgery. *Diagnostic Histopathology.* 18 (11) p. 468-477.

Shroyer, A. Coombs, L. Peterson, E. Eiken, M.C. et al (2003) The Society of Thoracic Surgeons: 30-day Operative Mortality and Morbidity Risk Models. *Annals of Thoracic Surgery.* 75 p.1856-1865.

Siafakas, N.M. Vermeire, P. Pride, N.B. Paoletti, P. Gibson, J. Howard, P. (1995) ERS Consensus Statement: optimal assessment and management of chronic obstructive pulmonary disease. *European Respiratory Journal.* 8 p. 1398-1420.

Smetana, G.W. (1999) Preoperative Pulmonary Evaluation. *The New England Journal of Medicine.* 340 (12) p.937-944.

Smetana, G.W. (2003) The case against routine preoperative laboratory testing. *The Medical Clinics of North America.* 87 p.7-40.

Smith, G. and Cantley, C. (1985) *Assessing healthcare: A study in organizational evaluation.* Milton Keynes: Open University Press.

Snashall, P.D. and Chung, K.F. (1991) Airway obstruction and bronchial hyper-responsiveness in left ventricular failure and mitral stenosis. *American Review of Respiratory Disease.* 144 (4) p, 945-956.

Society for Cardiothoracic Surgery (2013) *SCTS iData.* [Online] Available from: http://www.idata.scts.org/ [Accessed: 30th October, 2013].

Society for Cardiothoracic Surgery (2013) *Society for Cardiothoracic Surgery – Morriston Hospital.* [Online] Available from: http://www.scts.org/patients/hospitals/centre.aspx?id=43&name=morriston_hospital [Accessed: 11th January, 2014].

Spivack, S.D. Shinozaki, T. Albertini, J.J. Deane, R. (1996) Preoperative Prediction of Postoperative Respiratory Outcome. *Chest.* 109 p.1222-1230.

Stiller, K. App, B. Montarello, J. Wallace, M. Daff, M. et al (1994) Efficacy of Breathing and Coughing Exercises in the Prevention of Pulmonary Complications After Coronary Artery Surgery. *Chest.* 105 p.741-747.

Taggart, D.P. El-Fiky, M. Carter, R. Bowman, A. Wheatley, D.J. (1993) Respiratory Dysfunction After Uncomplicated Cardiopulmonary Bypass. *Annals of Thoracic Surgery. 56 p. 1123-1128.*

Talay, S. Ay, D. Kaygin, M.A. Erkut, B. Bayezid, O. (2011) The effect of partial cross clamping administration on postoperative healing of pulmonary functions for coronary artery bypass graft operations. *Saudi Medical Journal.* 32 (10) p.1022-1027.

The Criteria Committee of the New York Heart Association (1994) *Nomenclature and Criteria for Diagnosis of Diseases of the Heart and Great Vessels.* 9th Edition. Boston: Little Brown & Co.

Topal, A.E. and Eren, M.N (2012) Risk factors for the development of pneumonia post cardiac surgery. *Cardiovascular Journal of Africa.* 23 (4) p.212-215.

Toumpoulis, I.K Anagnostopoulos, C.E. DeRose, J.J. Swistel, D.G. (2004) European system for cardiac operative risk evaluation predicts long-term survival in patients with coronary artery bypass grafting. *European Journal of Cardio-Thoracic Surgery.* 25 p. 51-58.

Tucker, B. Jenkins, S. Davies, K. McGann, R. Waddell, J. King, R. Kirby, V. Lloyd, C. (1996) The physiotherapy management of patients undergoing coronary artery surgery: A questionnaire survey. *Australian Journal of Physiotherapy.* 42 (2) p.129-137.

Tully, P.J. Baker, R.A. Knight, J.L. (2008) Anxiety and depression as risk factors for mortality after coronary artery bypass surgery. *Journal of Psychiatric Research.* 64(3) p.285-290.

Tuman, K.J. McCarthy, R.J. March, R.J. Najafi, H. Ivankovich, A.D. (1992) Morbidity and Duration of ICU Stay After Cardiac Surgery. A Model for Preoperative Risk Assessment. *Chest.* 102 p. 36-44.

Urell, C. Emtner, M. Hedenstrőm, H. Tenling, A. Briedenskog, M. Westerdahl, E. (2011) Deep breathing exercises with positive expiratory pressure at a higher rate improve oxygenation in the early period after cardiac surgery – a randomised controlled trial. *European Journal of Cardio-Thoracic Surgery.* 40 p.162-167.

Van Belle, A.F. Wesseling, G.J. Penn, O.C.K.M, Wouters, E.F.M. (1992) Postoperative pulmonary function abnormalities after coronary artery bypass surgery. *Respiratory Medicine.* 86 (3) p.195-199.

Vohra, H. A. Goldsmith, I.R.A. Rosin, M.D. Briffa, N.P. Patel, R.L. (2005) The predictors and outcome of recidivism in cardiac ICUs. *European Journal of Cardio-Thoracic Surgery.* 27 p. 508-511.

Welsh Assembly Government (2006) *Designed for Life: Quality Requirements for Adult Critical Care in Wales*. Cardiff: Crown Copyright.

Welsh Assembly Government (2006) *A Therapy Strategy for Wales. The Contribution of Therapy Service to Transforming the Delivery of Health and Social Care in Wales.* Cardiff: Crown Copyright.

Welsh Government (2012) *Together for Health – A Cardiac Delivery Plan – Our Vision*. Cardiff: Crown Copyright. p.2-3.

Webber, B.A. and Pryor, J.A. (1993) Physiotherapy Skills: Techniques and adjuncts. In: Webber, B.A. and Pryor, J.A. (Eds): *Physiotherapy for Respiratory and Cardiac Problems*. Edinburgh: Churchill Livingstone. Chapter 8.

Weissman, C. Pulmonary Function after cardiac and thoracic surgery (2000) *Current Opinion in Anaesthesiology*. 13 p.47-51.

Weissman, C. Pulmonary Complications After Cardiac Surgery (2004) *Seminars in Cardiothoracic and Vascular Anesthesia.* 8 (3) p.185-211

Welsby, I.J. Bennett-Guerrero, E. Atwell, D. et al (2002). The association of complication type with mortality and prolonged stay after cardiac surgery with cardiopulmonary bypass. *Anesthesia & Analgesia.* 94 p.1072-1078.

Westaby, S. (1983) Complement and the damaging effects of cardiopulmonary bypass. *Thorax.* 38 p.321-325.

Wharton, N.M. and Linter, S.P.K. (2009) Survival Outcomes from Cardiac Surgery in Patients aged 80 years and over. *Anaesthesia*. 64 p.108-111.

Wigfield, C.H. Lindsey, J.D. Muñoz, A. Chopra, P.S. Edwards, N.M. Love, R.B. (2006) Is extreme obesity a risk factor for cardiac surgery? An analysis of patients with a BMI ≥40. *European Journal of Cardio-thoracic Surgery.* 29 p. 434-440.

Wilcox P. Baile, E.M. Hards, J. (1988) Phrenic nerve function and its relationship to atelectasis after coronary bypass surgery. *Chest.* 93 p.693-698.

World Heart Federation (2014) *Global facts & map on ischaemic heart diseases.* [Online] Available from: http://www.world-heart-federation.org/cardiovascular-health/global-facts-map/global-facts-map-on-ischaemic-heart-diseases/ [Accessed: 14th January, 2014].

Wynne, R. (2003) Variable Definitions: Implications for the prediction of pulmonary complications after adult cardiac surgery. *European Journal of Cardiovascular Nursing.* 3 p.43-52.

Wynne, R. and Botti, M. (2004) Postoperative Pulmonary Function in Adults After Cardiac Surgery With Cardiopulmonary Bypass: Clinical Significance and Implications for Practice. *American Journal of Critical Care.* 13 (5) p.384-393.

Yazdanian, F. Azarfarin, R. Aghdaii, N. Faritous, S.Z. Motlagh, S.D. Panahipour, A.(2013) Cardiac Variables as Main Predictors of Endotracheal Reintubation Rate after Cardiac Surgery. *The Journal of Tehran University Heart Center.* 8 (1) p. 42-47.

Yende, S. and Wunderink, R. (2002) Causes of Prolonged Mechanical Ventilation After Coronary Artery Bypass Surgery. *Chest.* 122 p.245-252.

Yin, Y. Peng, S. Huang, J. Hsieh, C. Tsai, T. Shih, Y. Peng, S. (2007) Risk Factors Affecting Adverse Outcomes of Cardiac Surgery in Patients Aged 70 Years and Older. *ACTA Anesthesiology Taiwan.* 45 p.197-204.

Zaidi, A.M. Fitzpatrick, A.P. Keenan, D.J.M. Odom, N.J. Grotte, G.J. (1999) Good Outcomes from Cardiac Surgery in the over 70s. *Heart*. 82 p.134-137.

Zaky, S.S. Seif, J. Abd-Elsayed, A.A. Bashour, C.A. (2009) Recurrent lung collapse due to unidentified phrenic nerve injury after cardiac surgery. *Minerva Anestesiologica*. 75 (9) p.533-536.

Zhu, F. Lee. A Chee, Y.E (2012) Fast-track cardiac care for adult cardiac surgical patients (review). *Cochrane Database of Systematic Reviews*. Issue 10.

Zupancich, E. Paparella, D. Turani, F. Munch, C. Rossi, A. Massaccesi, S. Ranieri, V.M. (2005) Mechanical ventilation affects inflammatory mediators in patients undergoing cardiopulmonary bypass for cardiac surgery: A randomized clinical trial. *The Journal of Thoracic and Cardiovascular Surgery*. 130 p. 378-383.